Instruments

THE MAGAZINE OF MEASUREMENT
INSPECTION · TESTING · CONTROL

MAR 19 1952
RARY

ncluding the

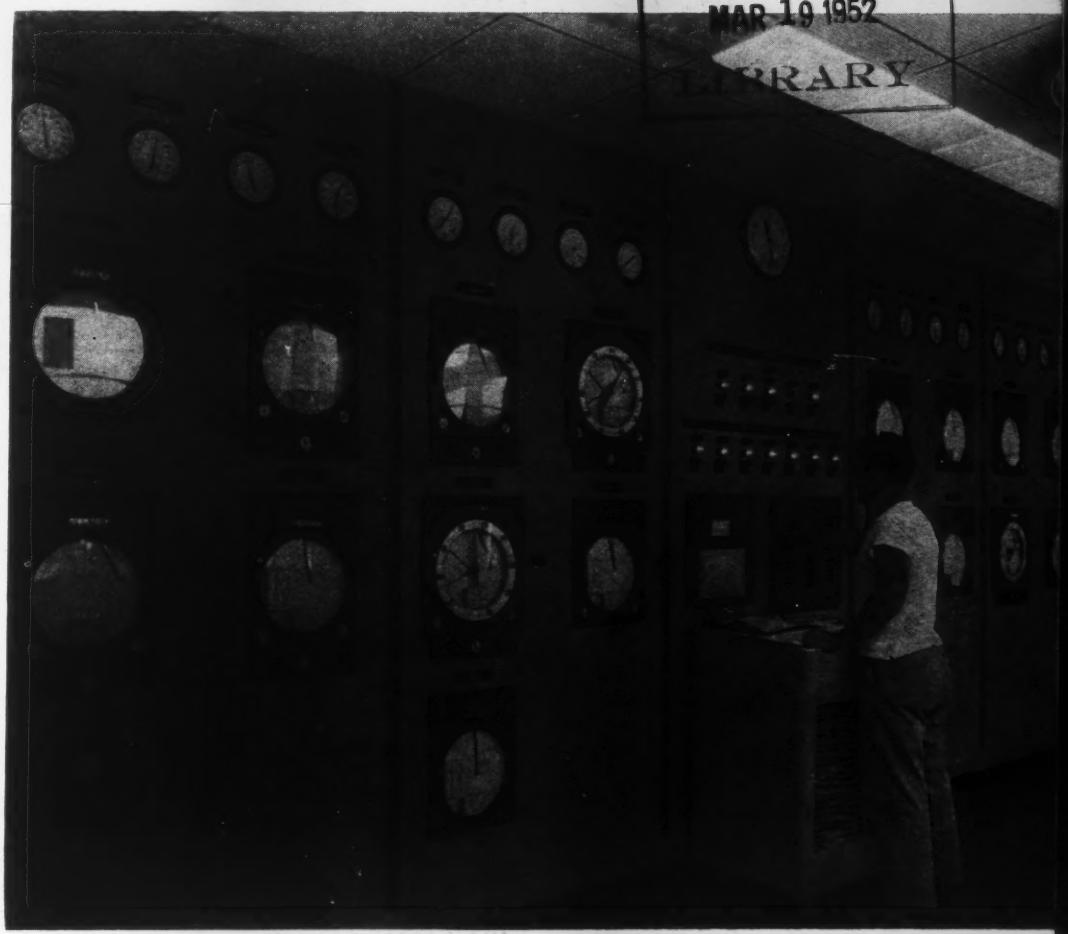
JOURNAL OF THE INSTRUMENT SOCIETY OF AMERICA

nd the

JOURNAL OF THE SOUTHERN CALIFORNIA METER ASSOCIATION

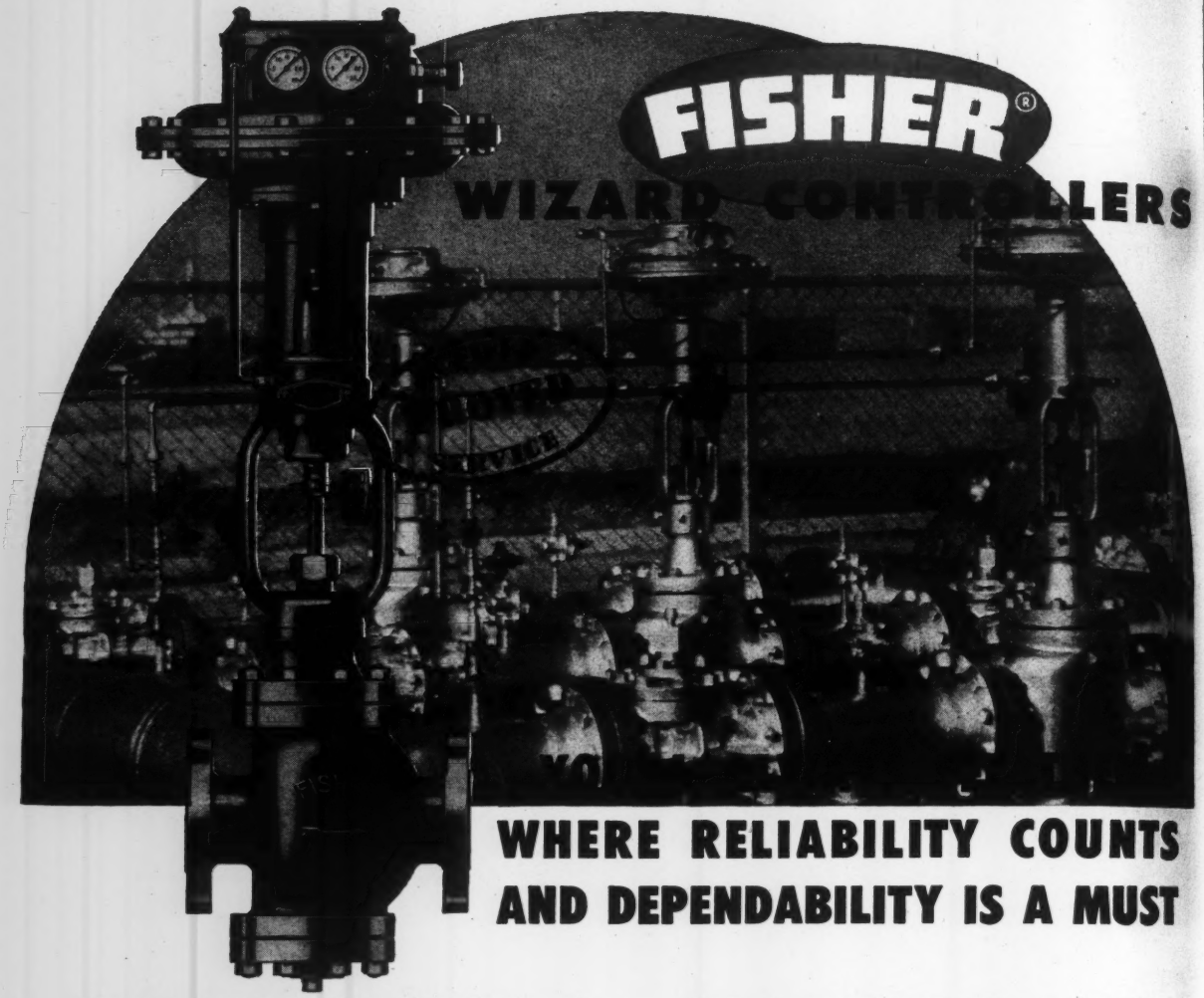
In this issue . . .

Mercury—
The Purest Metal
Instrument Evaluation
Rubber-plant Instrumentation
Oxygen-plant Instrumentation
Optimalizing Control
Instrument Electronics
Electrometric Titrometer
Transmitting Process Measurements
65 New Instruments
103 New Bulletins



Control room for crude unit at Standard Oil's Bakersfield, California refinery. ***(Photo courtesy Standard Oil of Calif.)***

Vol. 25 No. 3
MARCH • 1952



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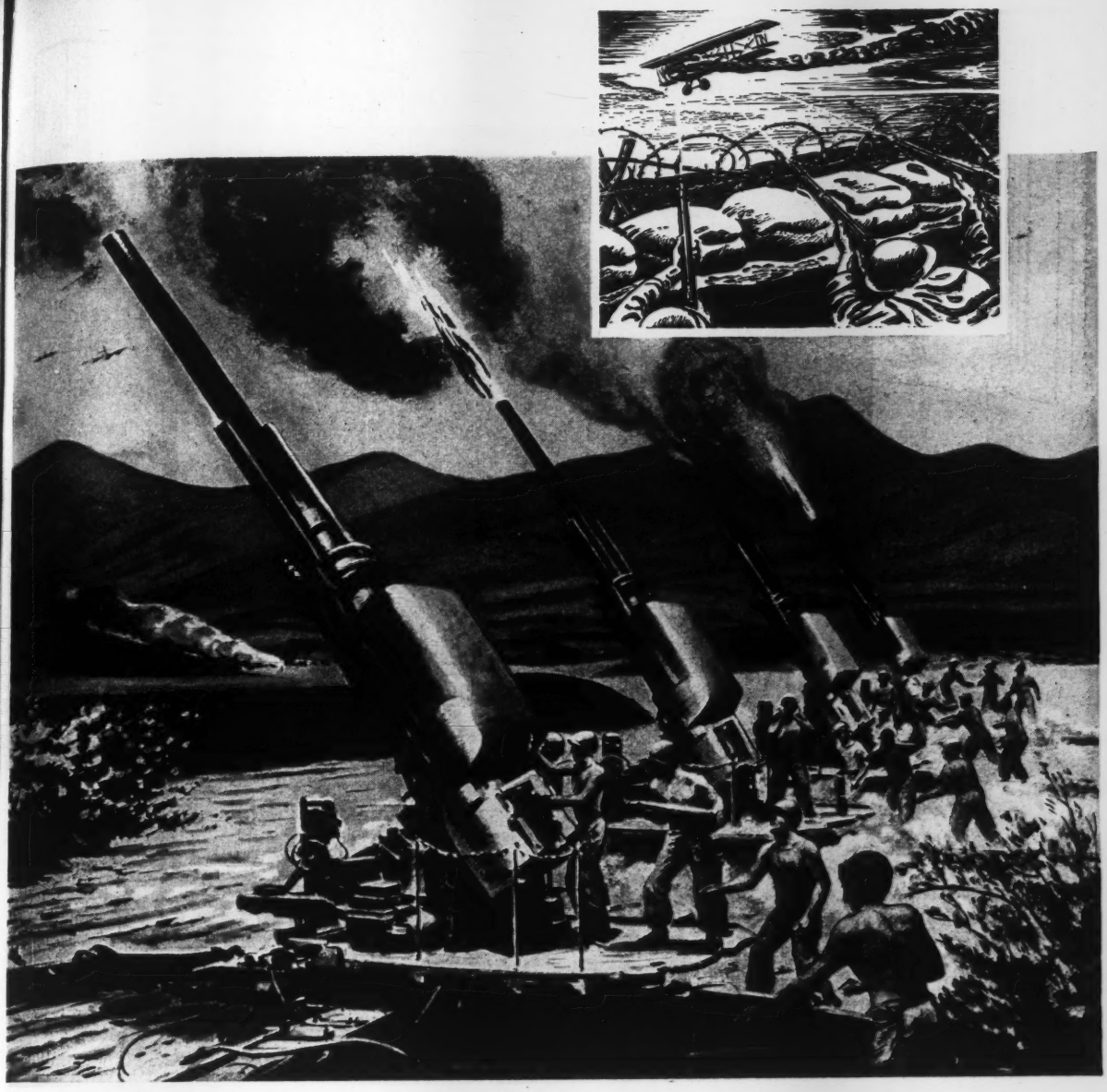

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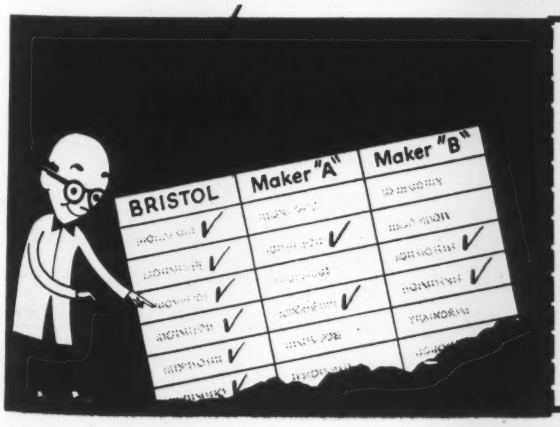

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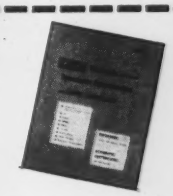

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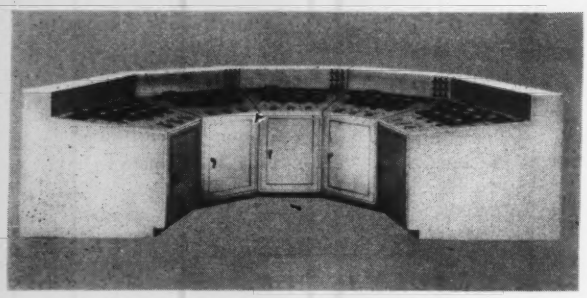

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Instruments
THE MAGAZINE OF MEASUREMENT INSPECTION · TESTING · CONTROL

Vol. 25 MARCH 1952 No. 3

FEATURE ARTICLES

Mercury—The Purest Metal 310
By J. B. Lawrence

Evaluation of Plant-control Instruments 313
By A. Bremer and B. D. Stanton

Instrumentation of a Synthetic-rubber Plant 314
By J. S. Detwiler

Instrumentation of Oxygen Plants 320
By J. H. Arnold

Optimalizing System for Process Control 324
By Y. T. Li

SERIAL

Instrument Electronics 328
By M. H. Aronson

THE MONTH'S NEW INSTRUMENTS 282

INSTRUMENTS ON THE MARCH

Network Calculator 344
Force Measurement 344
Radioactive-energy Transducer 344
Radioactive Isotopes in Industry 344
Radon Measurement and Control 346
Torquemeter Tests Centrifugal Pumps 346
Absolute Viscosity of Water 348
Tension Control 348

MANUFACTURERS' NEW LITERATURE 366

OTHER REGULAR FEATURES

Editorial Comment 281
Calendar of Important Instrumentation Events 364
Advertisers' Index 376

JOURNAL of the INSTRUMENT SOCIETY OF AMERICA 333

Continuous Recording Electrometric Titrometer 335
By H. E. Hallikainen and D. J. Pompeo

Electrical Transmitting and Transducing of Process Measurements 338
By C. G. Roper

Copyright 1952 by The Instruments Publishing Company, Inc. Office of publication, 1600 North Main Street, Pontiac, Illinois. Executive and Editorial Office, 921 Ridge Avenue, Pittsburgh 12, Pennsylvania.

Entered as second class matter, October 14, 1949, at the post office at Pontiac, Illinois, under the act of March 3, 1879.

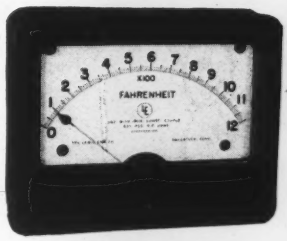
Continued on page 246

LEWIS

AUTOMOTIVE AND INDUSTRIAL TEMPERATURE MEASURING EQUIPMENT

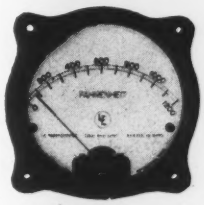
Sturdy Dependable Indicators —Suitable For Use In Moving Vehicles or For Permanent Installation

This instrument has been used extensively by the leading motor-car manufacturers for road testing on the "Proving Grounds" — where performance counts. Housed in a rectangular bakelite case, this reliable, fully compensated pyrometer is furnished with 6 in. hand drawn scales for greater accuracy. The Model 58PY is available for use with all standard thermocouple materials, in many ranges to suit the most exacting application.



MODEL 58PY

Manufactured with the same type of movement as our aircraft pyrometers, the Model 23B pyrometer is well suited for use in moving vehicles and has been successfully used in many marine diesel installations for measuring exhaust temperatures. It is housed in a 4 in. round bakelite case that is flanged for panel mounting, and is available in several ranges for use with various thermocouple materials.



MODEL 23B

The Model 20B series of indicators are patterned after our standard aircraft instruments and are supplied with 3" round steel cases suitable for panel installation. These compact, sturdy indicators have 2⅛ in. scales, are fully cold-end compensated and are available in many ranges for use with various thermocouple materials.

MODEL 20B

The Model 62RT4F resistance thermometer is a sturdy easy-to-read instrument with a 6 in. hand drawn scale. It is suitable for use in moving vehicles and is excellent for flight-test work. It is operated by an ordinary dry cell and is calibrated to standard "AN" bulb curves for various ranges in fahrenheit or centigrade.

MODEL 62RT4

THERMOCOUPLES for use with the above indicators are available in many styles for special applications. We have developed a complete line of aircraft, industrial and automotive thermocouples and would be pleased to offer our recommendation for your application.

THERMOCOUPLE LEAD WIRE for connecting thermocouples to the indicators is manufactured in iron-constantan, copper-constantan or chromel-alumel material with standard and special insulation. Use Lewis lead-wire with Lewis instruments and thermocouples for best results.

RESISTANCE BULBS for use as sensing elements for the 62RT4 thermometers are available in several types for various applications, for measuring free air or liquid temperatures. We invite inquiries on your application.

THE LEWIS ENGINEERING CO.

Specialists in Electrical Temperature Measurements

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FOSTER FLOW TUBE*

SHORT... not long!

The picture above sectionalizes one of our standard 12 inch Foster Flow Tubes. Put a rule on it, lengthwise and diametrically. What do you make the length-diameter ratio? About 1½ to 1?

Yes, 1½ to 1 is about the maximum ratio of length to diameter in the Foster Line of Flow Tubes in sizes 3" and above. Some units have less than a 1 to 1 ratio, particularly when high velocities are encountered. What does this mean to you in the way of installation costs and housing? You can readily picture how easy it is to set the Tube in a line. Just like a section of pipe. And with this compactness is an accuracy which not only equals the accuracy of conventional long primary devices but in most cases exceeds it. This is due to the greater pressure differentials for any given main-to-throat reduction.

Yes, you get great compactness and ease of installation with the Foster Flow Tube. You also can count on satisfactory accuracy. As for your specific applications, write us in detail giving both processing and installation requirements. Standard sizes come in all commercial pipe diameters, flanged or screwed connections. Standard lining is bronze; other metals to order.

*A Proved Flow Tube Added to Foster Line of Regulating Valves

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Instruments
THE MAGAZINE OF MEASUREMENT INSPECTION • TESTING • CONTROL

Published by

The Instruments Publishing Company
921 Ridge Avenue
Pittsburgh 12, Penna.

Richard Rimbach, *Publisher*
M. F. Behar, *Editor*
Milton H. Aronson, *Managing Editor*
James F. Emge, *Assistant Editor*

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London, W.C. 2, England. John C. N. Hughes, c/o T. G. Scott & Son, Ltd., 9 Arundel St., Telephone Temple Bar 1942

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Latin America and Australia $5.00, $8.00.
All other countries except those noted below $6.00, $10.00.

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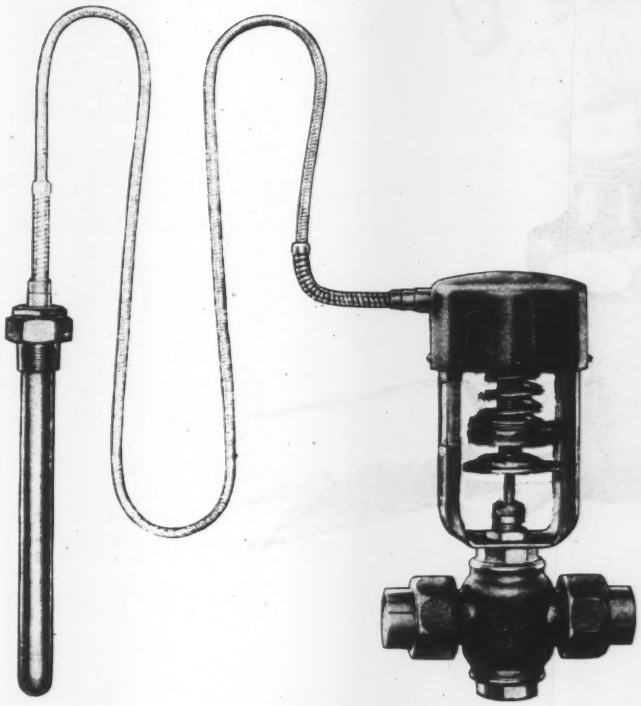

...for efficient, economical process control

● An automatic Sylphon Control can do a better job, any time, than hand-operated valves or "guess methods" do at governing temperatures. For Sylphon Controls maintain temperature that assures *uniform* processing conditions . . . *constant* product quality. They help reduce spoilage, wasteful overheating . . . save manpower and manhours. They do their jobs dependably—day in and day out.

Sylphon Temperature Regulator No. 999, pictured here, is one of the Sylphon line. Its outstanding features include stainless steel frame for minimum heat conduction from valve to regulator head . . . large size 2-ply Sylphon bellows for added power . . . less height and weight than other types. Self-operating—requires no auxiliary power source. Particularly suited for storage water heaters, metal plating tanks, bottle washers, treaters, slashers, etc.

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OHMITE JAN-TYPE WIRE-WOUND RESISTORS

MEET REQUIREMENTS OF JOINT ARMY-NAVY SPECIFICATION JAN-R-26A

STYLES AND SIZES

TAB-TERMINAL TYPE

Characteristics G and J

Style	Overall Length	Diameter	Watts
[illegible]	1-1/4"	1/2"	5
[illegible]	2"	11/32"	5
[illegible]	2-1/2"	11/32"	10
[illegible]	3"	11/32"	15
[illegible]	4"	11/32"	20
[illegible]	5"	11/32"	25
[illegible]	6"	11/32"	30
[illegible]	7"	11/32"	35
[illegible]	8"	11/32"	40
[illegible]	9"	11/32"	45
[illegible]	10"	11/32"	50
[illegible]	12"	11/32"	60
[illegible]	14"	11/32"	70
[illegible]	16"	11/32"	80
[illegible]	18"	11/32"	90
[illegible]	20"	11/32"	100
[illegible]	22"	11/32"	110
[illegible]	24"	11/32"	120
[illegible]	26"	11/32"	130
[illegible]	28"	11/32"	140
[illegible]	30"	11/32"	150
[illegible]	32"	11/32"	160
[illegible]	34"	11/32"	170
[illegible]	36"	11/32"	180
[illegible]	38"	11/32"	190
[illegible]	40"	11/32"	200
[illegible]	42"	11/32"	210
[illegible]	44"	11/32"	220
[illegible]	46"	11/32"	230
[illegible]	48"	11/32"	240
[illegible]	50"	11/32"	250
[illegible]	52"	11/32"	260
[illegible]	54"	11/32"	270
[illegible]	56"	11/32"	280
[illegible]	58"	11/32"	290
[illegible]	60"	11/32"	300
[illegible]	62"	11/32"	310
[illegible]	64"	11/32"	320
[illegible]	66"	11/32"	330
[illegible]	68"	11/32"	340
[illegible]	70"	11/32"	350
[illegible]	72"	11/32"	360
[illegible]	74"	11/32"	370
[illegible]	76"	11/32"	380
[illegible]	78"	11/32"	390
[illegible]	80"	11/32"	400
[illegible]	82"	11/32"	410
[illegible]	84"	11/32"	420
[illegible]	86"	11/32"	430
[illegible]	88"	11/32"	440
[illegible]	90"	11/32"	450
[illegible]	92"	11/32"	460
[illegible]	94"	11/32"	470
[illegible]	96"	11/32"	480
[illegible]	98"	11/32"	490
[illegible]	100"	11/32"	500

TAB-TERMINAL TYPE

with terminal hole to clear No. 8 screw

Characteristics G and J

Style	Overall Length	Diameter	Watts
[illegible]	3"	29/32"	35
[illegible]	4"	29/32"	50
[illegible]	6"	1-5/16"	75
[illegible]	8"	1-5/16"	100
[illegible]	9"	1-5/16"	125
[illegible]	10"	1-5/16"	150
[illegible]	12"	1-5/16"	175
[illegible]	14"	1-5/16"	200
[illegible]	16"	1-5/16"	225
[illegible]	18"	1-5/16"	250
[illegible]	20"	1-5/16"	275
[illegible]	22"	1-5/16"	300
[illegible]	24"	1-5/16"	325
[illegible]	26"	1-5/16"	350
[illegible]	28"	1-5/16"	375
[illegible]	30"	1-5/16"	400
[illegible]	32"	1-5/16"	425
[illegible]	34"	1-5/16"	450
[illegible]	36"	1-5/16"	475
[illegible]	38"	1-5/16"	500
[illegible]	40"	1-5/16"	525
[illegible]	42"	1-5/16"	550
[illegible]	44"	1-5/16"	575
[illegible]	46"	1-5/16"	600
[illegible]	48"	1-5/16"	625
[illegible]	50"	1-5/16"	650
[illegible]	52"	1-5/16"	675
[illegible]	54"	1-5/16"	700
[illegible]	56"	1-5/16"	725
[illegible]	58"	1-5/16"	750
[illegible]	60"	1-5/16"	775
[illegible]	62"	1-5/16"	800
[illegible]	64"	1-5/16"	825
[illegible]	66"	1-5/16"	850
[illegible]	68"	1-5/16"	875
[illegible]	70"	1-5/16"	900
[illegible]	72"	1-5/16"	925
[illegible]	74"	1-5/16"	950
[illegible]	76"	1-5/16"	975
[illegible]	78"	1-5/16"	1000

FERRULE-TERMINAL TYPE

Characteristics G and J

Style	Overall Length	Diameter	Watts
[illegible]	1-7/16"	1-5/16"	140
[illegible]	1-5/8"	1-5/16"	115
[illegible]	1-7/16"	1-5/16"	85
[illegible]	1-1/8"	1-1/16"	50
[illegible]	1-7/16"	1-1/16"	60
[illegible]	1-15/16"	3/4"	30
[illegible]	2-3/8"	3/4"	14

FLAT (Stack Mounting) TAB-TERMINAL TYPE

Characteristics G and J

Style	Overall Length	Width of Core	Width*	Watts
[illegible]	2-1/2"	1-3/16"	1/2"	15
[illegible]	3-1/2"	1-3/16"	1/2"	25
[illegible]	4-1/2"	1-3/16"	1/2"	35
[illegible]	5"	1-3/16"	1/2"	40
[illegible]	6"	1-3/16"	1/2"	50
[illegible]	7-1/2"	1-3/16"	1/2"	65

*Width here as MR Characteristic "S"

AXIAL-TERMINAL TYPE

Characteristics G and J

Style	Length of Core**	Diameter	Watts
[illegible]	1-3/8"	1/4"	5
[illegible]	3"	3/8"	10

**1-1/2" wire leads

Ohmite offers an unusually complete line of resistors that meet the most rigid requirements (Characteristics "G" and "J") of Joint Army-Navy Specification JAN-R-26A. To meet these requirements, resistors must pass severe moisture resistance and thermal shock tests. They are required to withstand strenuous vibration applied for five continuous hours. And, they must satisfy the requirements of many other tests, including momentary overload, mechanical strength, and terminal strength.

Of the 28 different resistor styles listed in JAN-R-26A, Ohmite offers 23 styles that meet these specifications. These styles represent the most popular resistors, and are available in a complete range of resistance values, in the types and sizes listed.

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RHEOSTATS • RESISTORS • TAP SWITCHES

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. . . gives fastest response, longest sustained accuracy, lowest installation cost

Simpler in design, simpler and much less expensive to install, far easier to maintain . . . the all-metal Foxboro mercury-less d/p Cell offers greater speed of response, permitting closer flow control, than has ever been possible before. Its negligible displacement and corrosion-proof construction of Type 316 Stainless Steel eliminate usual maintenance problems, even in service on highly corrosive or viscous fluids previously considered unmeasurable.

The Foxboro d/p Cell measures differential pressure by the force-balance principle and transmits pneumatically to indicating, recording, or controlling receivers. Small, compact, weighs as little as 19 lb. Ranges: from 25" to 800" H_2O. Working pressure ratings up to 4000 psi. Steel or stainless steel construction. Inherent over-range protection. Easy in-the-field calibration and range changes. Optionally available with pre-assembled manifold piping shown in photo above.

Thousands of d/p Cells now in use throughout industry, with many repeat orders now on our books, indicate the wide acceptance and successful performance of this revolutionary development for the measurement of liquid, steam, gas, or air flow. Write for detailed Bulletin 420. **The Foxboro Company, 463 Neponset Avenue, Foxboro, Massachusetts, U. S. A.**

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- No mercury
- No leveling
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INSTRUMENTS

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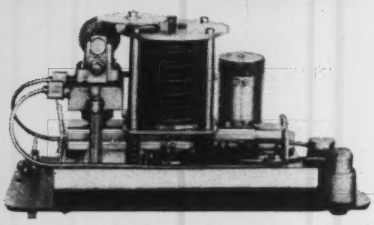
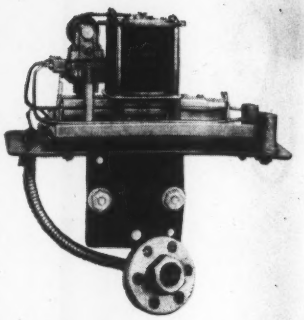
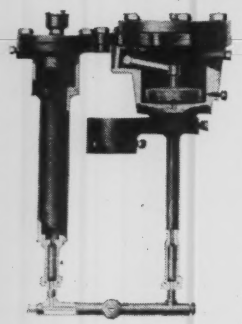
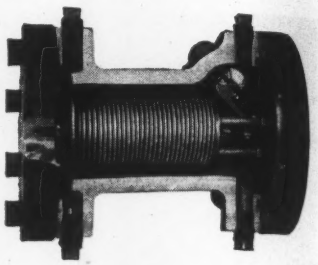
MEASURE



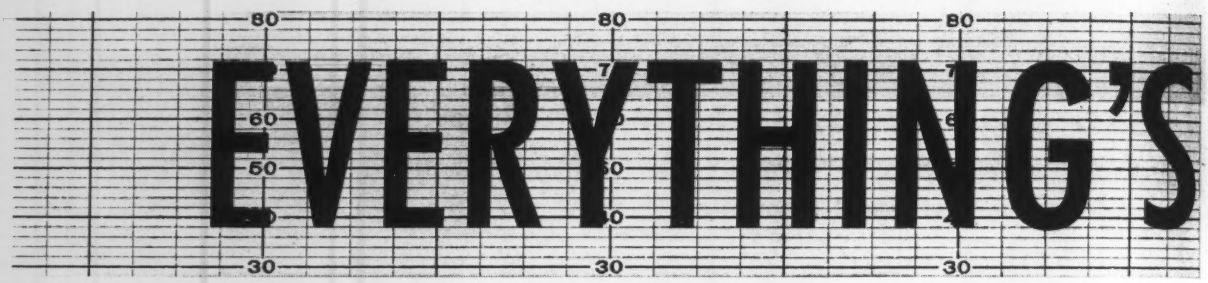


Taylor TRANSAIRE* Transmitters virtually eliminate time lag in measuring smallest changes in variables. Temperature model (*left*) has derivative action, SPEED-ACT*, in measuring circuit, which assures dynamic accuracy under changing conditions. Pressure model (*right*) detects changes of .1% of range span, accurate to ½% of range span rather than pressure level. Available in 20 and 40 lb. pressure spans to 400 lbs. limit, 50 and 100 lb. pressure spans to 1,000 lbs. limit. Temperature and barometric compensation.

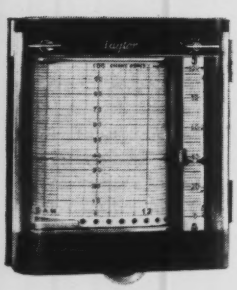




Taylor Differential Pressure Manometers give accurate, dependable measurement of flow, liquid level and specific gravity. Mercury model (*left*) is accurtae to ½ of 1% of the range, has interchangeable tubes for continuous ranges from 10 to 500 inches of water. Aneroid (mercuryless) models (*right*) of 300 and 1500 psi working pressures. Range limits: 0 to 20″ to 0 to 500″ water. Also available in all-316 stainless steel for corrosive mediums.

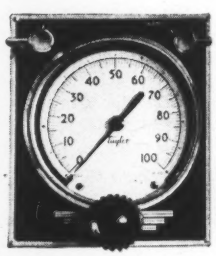


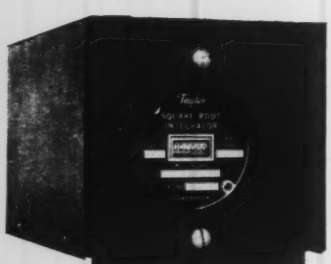
RECEIVE



½% Accuracy of TRANSET* Recorder (*left*) takes fullest advantage of Transaire Transmitter precision. Recorder has automatic-manual unit, remote set-point adjustment, valve position indicator. Takes 4⅜″ x 5″ panel space. 30 day linear chart, 3 hours visible.

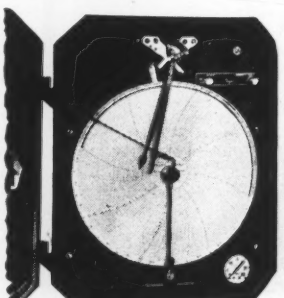
The TRANSET Indicator (*right*) has all the features of the TRANSET Recorder, but gives no chart record. Easy reading 3½″ dial, mounts in same size panel opening as TRANSET Recorder.





TRANSET Receiving Flow Integrator (*left*) also takes just 4⅜″ x 5″ panel space. It totals the flow of liquids and gases, is available in square root or linear forms. Like the other TRANSET Receivers, its small size makes it ideal for graphic panels.

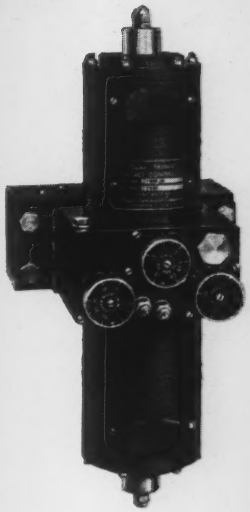
Taylor 84JF Recording Receiver (*right*) is an alternate part of the TRANSET System designed for those who want matching cases on conventional panel boards. Has all the features of the small TRANSET Recorder, but utilizes standard 12″ circular charts.

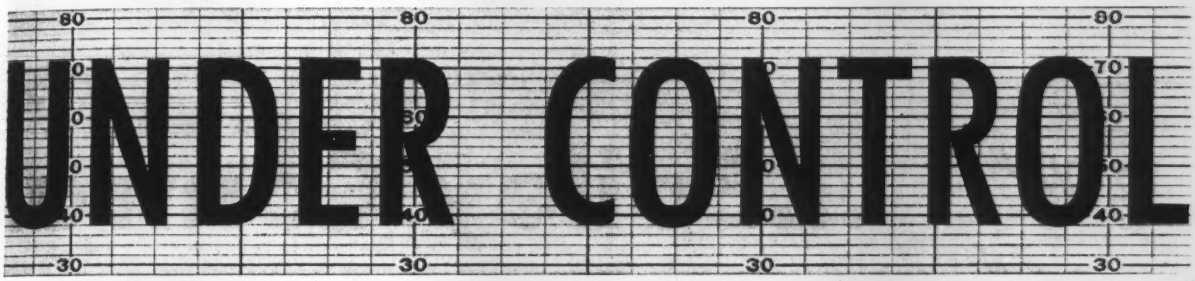


CONTROL

The TRI-ACT* Controller (*right*) is a force-balance pneumatic controller with a new circuit embodying three control responses: proportional, PRE-ACT* (rate action) and automatic reset. Gives a precision of control never before believed possible, with faster, more stable recovery on load changes, no overpeaking on start-up. Can be locally or panel mounted.

BI-ACT* is TRI-ACT's little brother. The BI-ACT Controller (*left*) is a lower cost instrument with *two* control responses, proportional and automatic reset, both adjusted with *one* stability knob. It's the ideal instrument for dependable, accurate performance on those applications where the quality of control obtainable with derivative response is not essential.





with Taylor's TRANSET System regulating any process variable*

*Trade-Mark

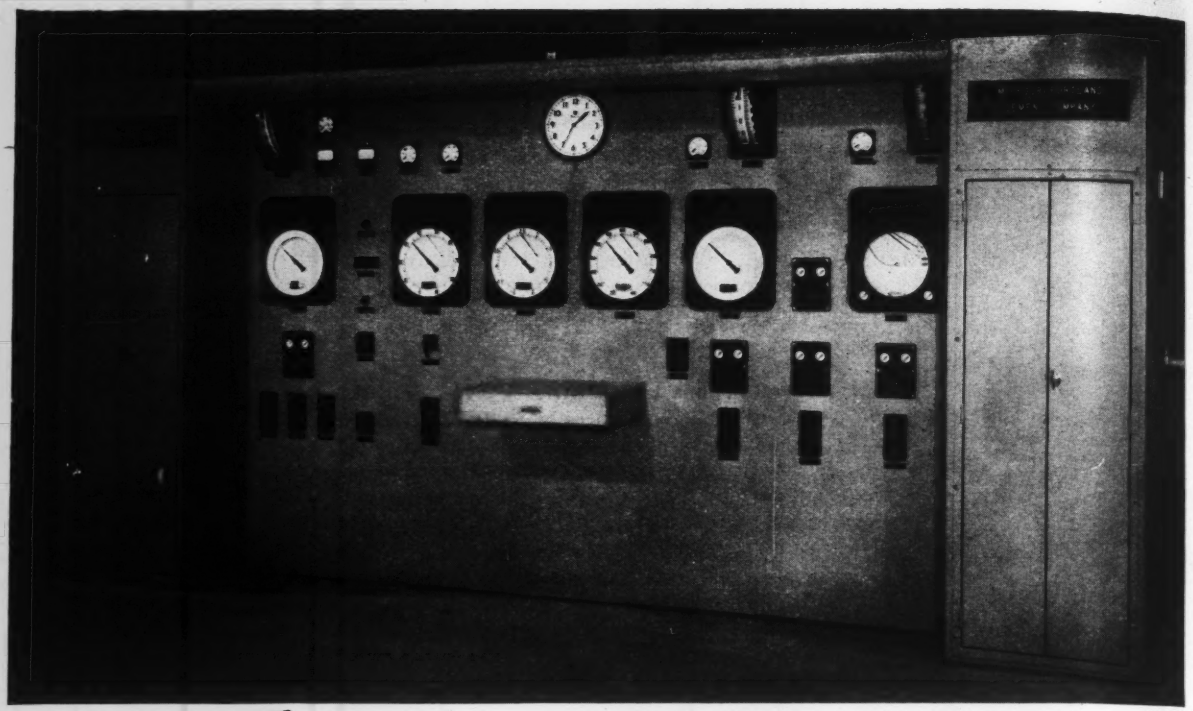
THE ANSWER to almost any industrial control problem is on these pages. Taylor's New TRANSET Control System can control practically any process variable, with a precision never before possible.

A wide variety of units available within each of the system's three steps, measuring, controlling and receiving, makes TRANSET Control adaptable to fit your control requirement perfectly. Each unit incorporates brand-new features and techniques, and the units in each step are designed to take fullest advantage of the superior performance of units in the other steps. It's an unbeatable team that can cut costs and improve product quality in any process industry.

For full information on how you can profit from Taylor TRANSET Control, ask your Taylor Field Engineer, or write for **Bulletin 98097.** Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

Instruments for indicating, recording and controlling temperature, pressure, flow, liquid level, speed, density, load and humidity.

Taylor Instruments
MEAN
ACCURACY FIRST
IN HOME AND INDUSTRY



Main Panel Board for control of 3000 bbl per day Kiln at Missouri Portland Cement Company, St. Louis, Missouri.

3 Ways Better

...Bailey Control for Rotary Kilns

Bailey Control for Rotary Kilns gives you better performance three ways:

1. Economical Operation
2. Uniform Quality of Product
3. Reduced Maintenance

These are advantages which can be achieved when all phases of kiln operation are coordinated to work together as a team. Here's how Bailey Kiln Control can help you get all three.

ECONOMICAL OPERATION

With Bailey Combustion Control you can be certain that you are getting maximum product for every unit of fuel you burn. Bailey Control closely guards the Fuel-Air Ratio, Hood Draft, Fuel Feed, Clinker Cooling and the Temperature of Air for Combustion.

UNIFORM QUALITY OF PRODUCT

Bailey Instruments and Controls can help you achieve a uniform high grade product. Measurements of temperatures, kiln speed, combustibles content, and oxygen content can be transmitted to recorders on centrally located control boards like the one shown. There is no sacrifice of accuracy or speed of response. High temperature alarm contacts may also be provided with Bailey Pyrometers as a further aid in achieving optimum uniformity of product.

REDUCED MAINTENANCE

By maintaining uniform temperatures and excess air conditions in the kiln, Bailey Controls help to reduce to a minimum costly refractory repairs and wear and tear on auxiliary equipment.

Bailey Meter Company has a staff of engineers who are experts in the control of rotary kilns. Assure yourself of optimum kiln performance. Let one of these men help plan your Kiln Control System. P-22

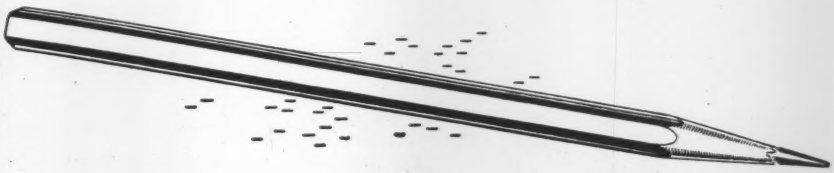
BAILEY METER COMPANY

1041 IVANHOE ROAD • • • CLEVELAND 10, OHIO

Controls for Processing

TEMPERATURE
PRESSURE
% OXYGEN
% COMBUSTION
FLOW
LEVEL
DENSITY
RATIO

USING ANY OF THESE?



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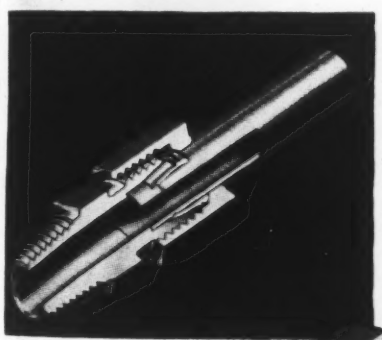
SAVE TIME AND MONEY

with Weatherhead

ERMETO®

This fitting will save you up to 60% on steel tubing installation time . . . up to 40% on copper and aluminum. You can make tube connections at all pressures —economically at low pressures, *safely and economically* at elevated hydrostatic pressures. There's NO FLARING, NO THREADING, NO WELDING, NO SOLDERING—*fast installation* with only a wrench . . . no special tools required. Disassembly is easy . . . and you are assured of a pressure-tight joint every time you retighten. Ermeto meets J. I. C. Requirements.



The Weatherhead ERMETO sleeve makes the difference! See how nut presses sleeve as threads engage. Forces acting on sleeve cause it to bow slightly and actually bite into the surface of the tube. This strengthens the seal, distributes vibration strains and holds a constant tension between body and nut to prevent loosening.

WRITE for complete details—get ERMETO CATALOG No. E-1457 for information on ERMETO sizes, types, installation. Address: Dept. S, THE WEATHERHEAD COMPANY, Cleveland 8, Ohio. In Canada, THE WEATHERHEAD COMPANY, LTD., St. Thomas, Ontario.

	✓	Machine Tools
	✓	Marine Engines
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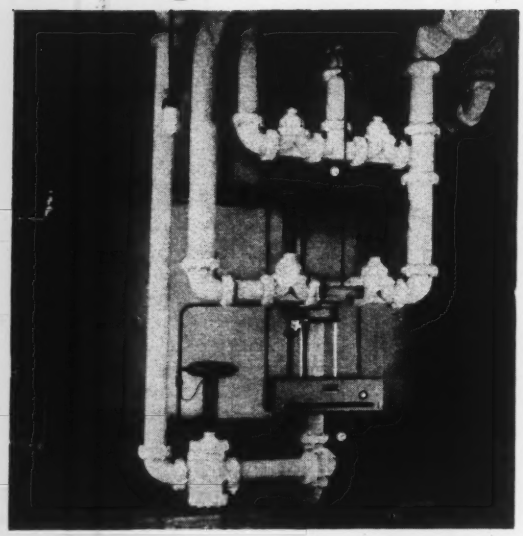
	✓	Textile Processing Equipment

The Mark of Quality

WEATHERHEAD

FIRST IN HYDRAULIC CONNECTIONS



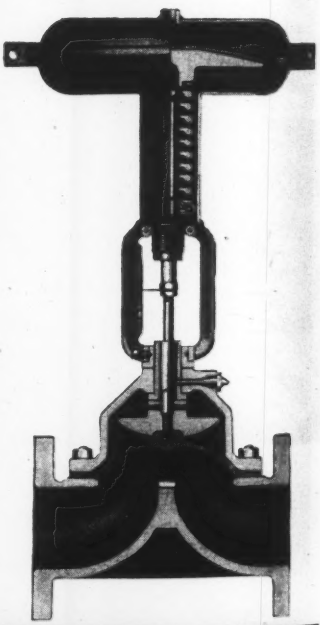
HOW K & M VALVES HELP "SOFTEN UP" 120,000 GALLONS OF HARD WATER PER HOUR

The mineral salts in hard water can cause extremely costly damage to the boilers of a power plant.

At one of America's most important industrial plants, a massive installation of cation and anion exchangers "softens up" or demineralizes water at the rate of 120,000 gallons per hour, thus protecting the steam generators.

The big exchanger units are complicated and require trustworthy regulation of flow at many points. 125 K & M Saunders-Type valves in the assembly do the job with safety, certainty and precision. Moreover, the installation has been so successful that the company is building a similar one, for which K & M valves are also being used.

Leaders in many industries look to K & M valves for proved sensitivity and endurance. K & M is geared to handle the smallest or largest problem in control valves, however exacting the requirements. Our engineers invite your inquiries.



K&M

KIELEY & MUELLER, INC.

Valve Makers Since 1879

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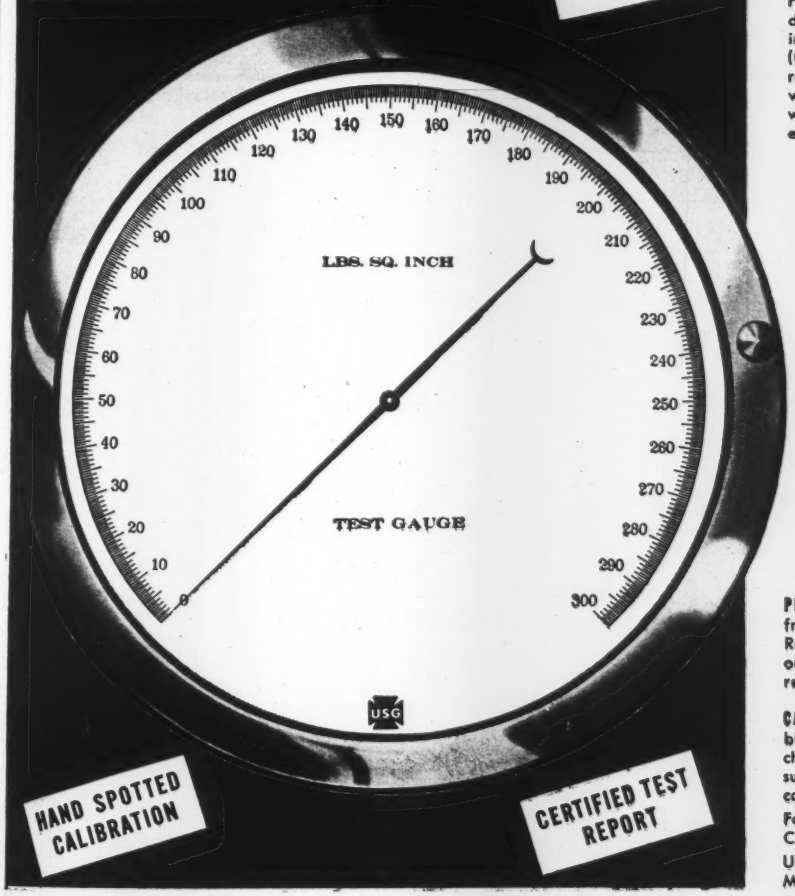
"300,000 LB. CAPACITY RIEHLE COMPRESSION TESTING MACHINE, MADE BY RIEHLE TESTING MACHINE DIVISION OF AMERICAN MACHINE AND METALS, INC."

For Peak Precision

USG LABORATORY TEST GAUGES

Wherever you require *peak precision* from a gauge—for compression or tensile strength testing machines, or for replacing or supplementing dead weight testers or manometers—you can use the accuracy of USG Laboratory Test gauges to advantage.



PEAK PRECISION—½ of 1% of the indicated reading above 20% of the maximum dial range and one part in 500 (0.2%) below 20% of the maximum dial range. A Certified Test Report is furnished without charge for applying corrections when instrument is used at accuracies higher than ½ of 1% of indicated reading.

PRECISION DRAWN TUBE—Drawn from phosphor bronze, beryllium copper, or 403 stainless steel—depending on pressure range. All tubes are specially treated to produce minimum hysteresis and drift.

PRECISION MOVEMENT—Aircraft quality for highest sensitivity. Nickel-dipped bronze with extra long bearings and heavy bronze bushing fitted with nickel silver pinions and arbors.

PRECISION CALIBRATION—Graduations are individually hand-spotted and engraved on a white background. Dial may be rotated 10° for zero adjustment to compensate for preloading.

DIAL SIZES—12" and 16".

PRESSURE RANGES—All pressure ranges from 30" Vacuum and 15 to 20,000 p.s.i. Ranges over 30,000 p.s.i. on special order. Suppressed scales available on request.

CASE AND RING—Cast aluminum case, black finish. Cast brass ring with polished chromium finish. Flush panel mounting or surface mounting with back or lower connection.

For additional information, write for USG Catalog 64.

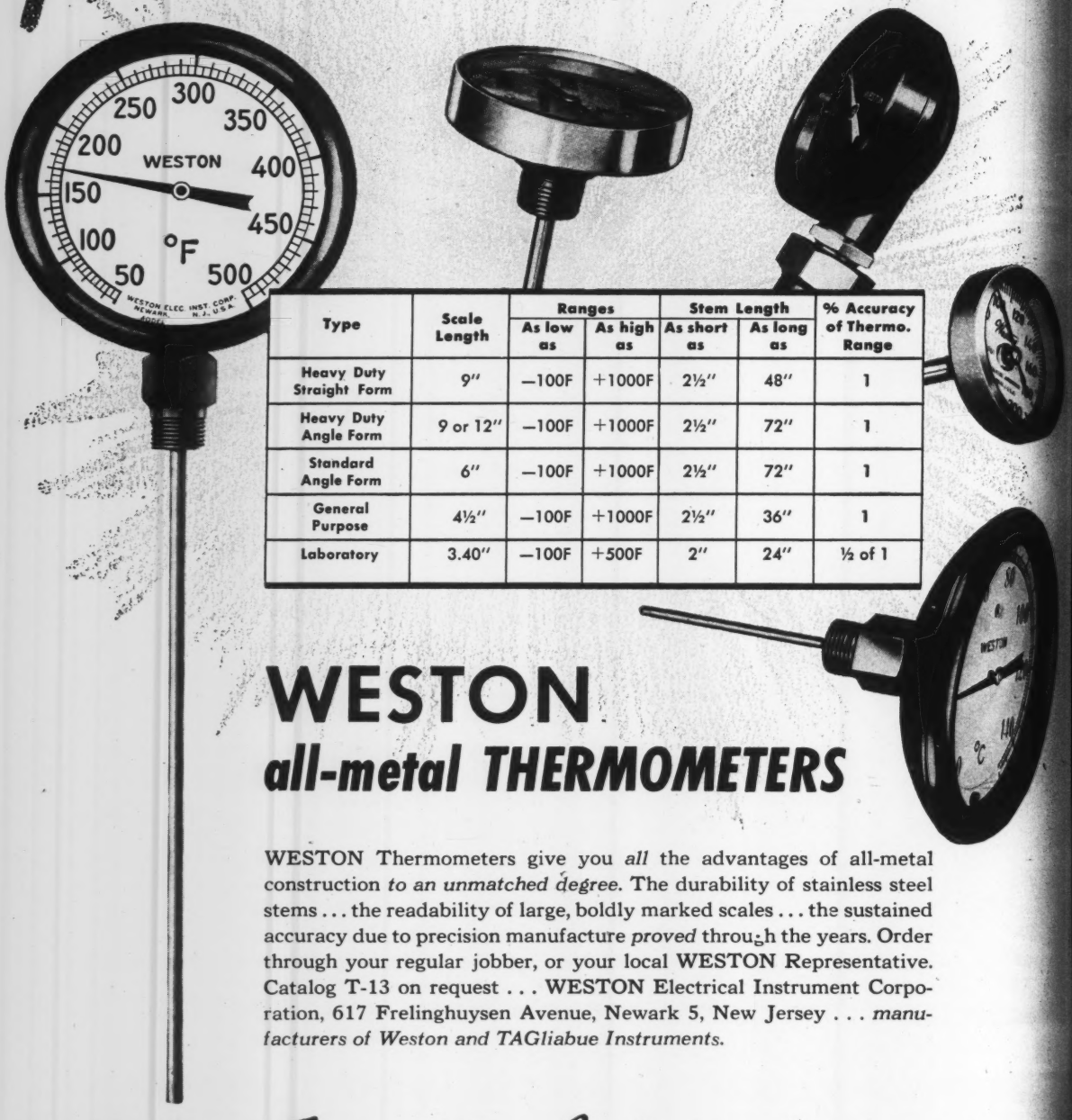
United States Gauge, Division of American Machine and Metals, Inc., Sellersville, Pa.

Quality Gauges Engineered for Enduring Accuracy UNITED STATES GAUGE

PRODUCTS OF UNITED STATES GAUGE . . . Absolute Pressure Gauges • Aircraft Instruments • Air Volume Controls • Altitude Gauges • Boiler Gauges Chemical Gauges • Mercury, Gas, and Vapor Dial Thermometers • Glass Tube and Industrial Thermometers • Flow Meters • Inspectors' Test Gauges Precision Laboratory Test Gauges • Marine, Ship and Air-Brake Gauges • Voltmeters • Ammeters • Welding Gauges.

OTHER DIVISIONS OF AMERICAN MACHINE AND METALS, INC. AT SELLERSVILLE, PA.: GOTHAM INSTRUMENTS, AND AUTOBAR SYSTEMS.

Available in broadest selection of types, ranges, stem lengths



Type	Scale Length	Ranges		Stem Length		% Accuracy of Thermo. Range
		As low as	As high as	As short as	As long as	
Heavy Duty Straight Form	9"	—100F	+1000F	2½"	48"	1
Heavy Duty Angle Form	9 or 12"	—100F	+1000F	2½"	72"	1
Standard Angle Form	6"	—100F	+1000F	2½"	72"	1
General Purpose	4½"	—100F	+1000F	2½"	36"	1
Laboratory	3.40"	—100F	+500F	2"	24"	½ of 1

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WESTON Thermometers give you *all* the advantages of all-metal construction *to an unmatched degree.* The durability of stainless steel stems . . . the readability of large, boldly marked scales . . . the sustained accuracy due to precision manufacture *proved* through the years. Order through your regular jobber, or your local WESTON Representative. Catalog T-13 on request . . . WESTON Electrical Instrument Corporation, 617 Frelinghuysen Avenue, Newark 5, New Jersey . . . *manufacturers of Weston and TAGliabue Instruments.*

WESTON *Temperature Instruments* INDICATE—RECORD—CONTROL

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VALVE ACTION *with*

CLIMAX RELAYS

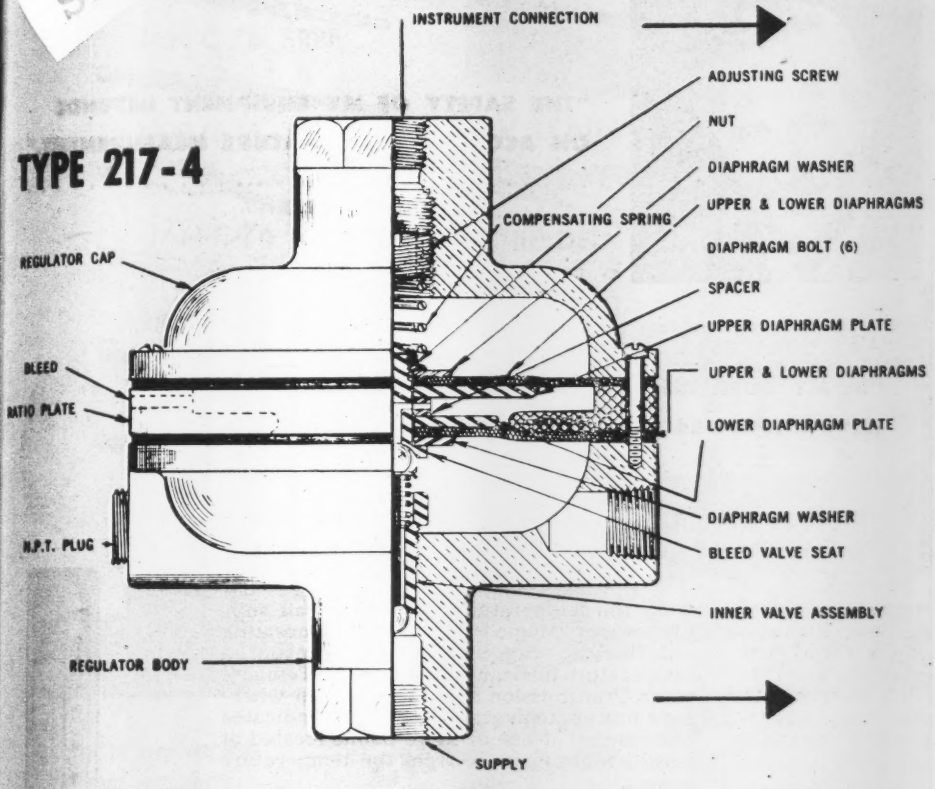
STEP-UP

SPEED-UP

SLOW-UP

BS&B

TYPE 217-4



For almost any pressure, input or output variation in the supply medium to the control valve, there's a Climax Relay to do the job efficiently and accurately. You can deliver pressure output to step up action, boost the capacity of low-limit controls to handle larger loads, speed the valve loading or reduce it, eliminate pressure lag on long supply medium lines, control high steam pressures with balanced diaphragm regulators.

New BS&B Climax Relays are being constantly developed to meet the demands of the latest methods and equipment. Their accuracy and sensitivity will contribute much to the efficiency of your processing system. They will, in many cases, provide a great economy by permitting your valves and controls to expand their designed functions.

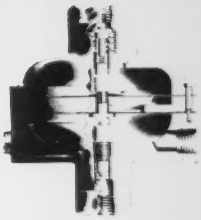
Write for Catalog Section 109—"Relay Regulators." Illustrated, complete with descriptions, application and installation data.

CLIMAX BS&B CONTROLS

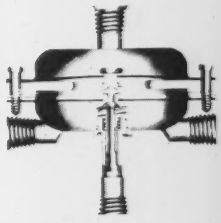
BLACK, SIVALLS & BRYSON, INC.

Climax Controls Division Dept. 4-V3

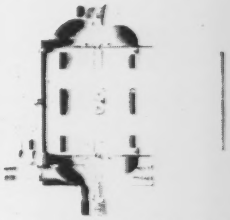
7500 East 12th St. Kansas City 3, Missouri



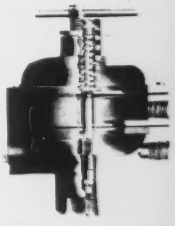
NEW TYPE 227 Delayed action, fixed ratio. Permits full valve travel with standard diaphragm pressure ranges on series-operating diaphragm control valves in combination with Type 217-2R relay.



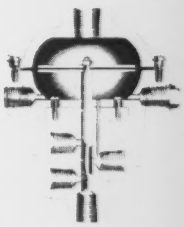
Fixed Ratio—to meet demands of control pressures beyond the range of usual instrument pressures; permits low-limit controls to secure higher loading pressure.



Variable Ratio—creates a loading of pressure balanced diaphragm valves to permit the control of high steam pressures in reboilers or fractionating kettles, where steam pressures must vary for varying products.



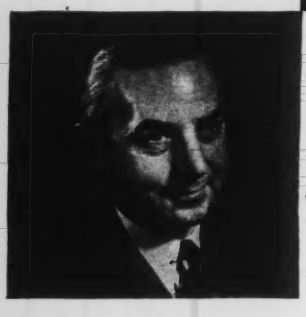
Reverse Action Relay for maximum pressure output at minimum input—or vice versa. Or, in bypass installation, reverse valve action in relation to pilot action, when occasionally required.



1 to 1 Ratio—will eliminate air exhaust and input pressure lag where long supply medium lines are used.

"I MUST KNOW EXACT TEMPERATURES TO MAINTAIN PRODUCT QUALITY."

"THE SAFETY OF MY EQUIPMENT DEPENDS ON ACCURATE TEMPERATURE MEASUREMENT."



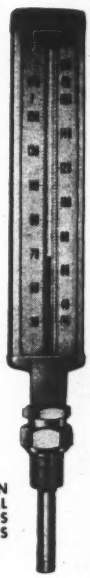
"IN MY BUSINESS, PRECISE TEMPERATURE RECORDING MEANS PRECISE COST CONTROL."

You know why accurate temperature measurement is vital in *your* business. You also know it takes skillful engineering, the highest quality materials and workmanship to create consistently accurate, long-life instruments. That's exactly what you get in every American Thermometer and Temperature Indicator and Recorder you buy.

Depending upon type and requirements, these precision instruments are built in ranges from minus 100°F. to plus 3000°F., with actuation by mercury, vapor pressure, gas, bi-metal or thermocouple. For accurate remote indication or recording, up to 250 feet from the temperature source, we can supply famous "Magic Pulse" self-compensating capillary tubing with mercury-actuated temperature instruments. American Temperature Transmission systems are ideal wherever process temperatures must be indicated or recorded at one or more points located at considerable distance from the temperature source.

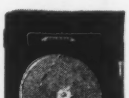
The complete line of American Thermometers and Temperature Measuring Instruments simplifies selection for specific applications. Write for a copy of our new catalog.

Stocked and Sold by Leading Distributors

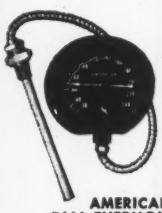


AMERICAN INDUSTRIAL GLASS THERMOMETERS

AMERICAN ELECTRONIC TEMPERATURE INDICATORS



AMERICAN RECORDING THERMOMETERS



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MAKERS OF 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'HANCOCK' VALVES, 'ASHCROFT' GAUGES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES. BUILDERS OF "SHAW-BOX" CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.

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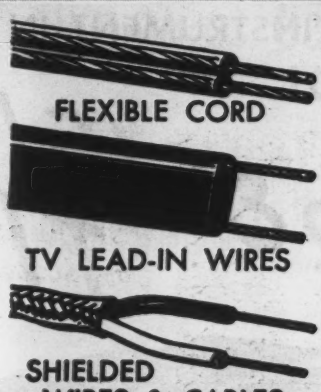
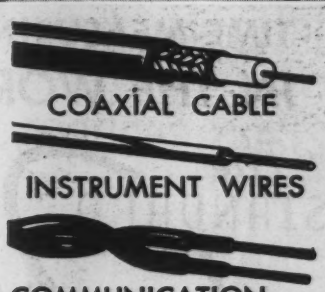
—FOR SAFETY AND DEPENDABILITY BEYOND SPECIFICATION





SPECIAL WIRES & CABLES TO SPECIFICATION

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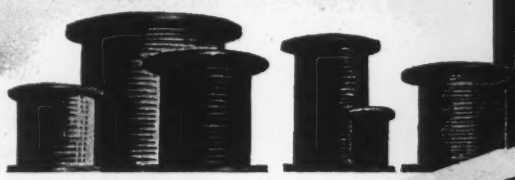
WIRES and CABLES



JAN-C-76 APPROVED WIRES
80°–90°–105°C HOOK-UP WIRE
SHIELDED WIRE AND CABLE
FLEXIBLE CORDS
COAXIAL CABLE
TELEVISION LEAD IN CABLE
GAS TUBE HIGH TENSION CABLE
OIL BURNER IGNITION CABLE
BLASTING WIRE
THERMOSTAT CABLE
BELL AND OFFICE WIRE
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CHESTER makes them all!

All Chester wire and cable features the extra dependability, long service life and easier working qualities of plastic insulation. Their tough, impervious plastic coats provide maximum immunity to abrasion, weather, oil and most chemicals. They are smooth, pull through conduit with minimum effort and present a fine appearance in exposed locations.

There's a Chester single or multi-conductor wire or cable for practically every indoor or outdoor requirement including many special constructions for the electrical, electronic, TV, radio, telephone and other industries. Why not write today for full information?

"Chesty" says—

Write today for your free copy of the Chester Wire and Cable catalog. A complete guide to plastic covered wire and cable for every electronic and electrical application. Please address inquiries on company letterhead.

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CHESTER, NEW YORK

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YOU ARE LOOKING AT
THE MOST Accurate and MOST Rugged
TIME-MEASURING INSTRUMENT IN GENERAL USE
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The STANDARD PRECISION TIMER

It's There — in the "Clutch"
the Heart of STANDARD'S
Uncanny Precision
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WE MEASURE ELAPSED TIME
DOWN TO INTERVALS OF
1/1000th SECOND

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SPLITTING the SPLIT SECOND

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TIMERS AND CHRONO-TACHOMETERS
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How CROSBY'S BALANCED AREA DESIGN eliminates back pressure effects

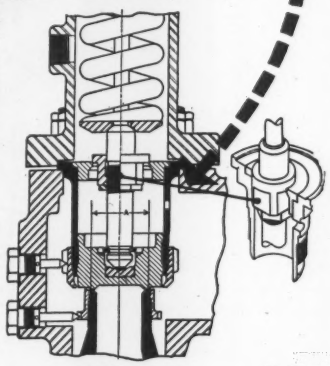


Fig. 1

When a standard relief valve on gas or vapor service is installed, where back pressure exists one of two undesirable effects will occur:

Constant Back Pressure — The back pressure acts on part of the upper and the overhanging part of the lower surface of the disc, cancelling out the back pressure force. There remains, however, a force acting on the top partition of disc (area A) which increases the spring load and causes the valve to pop "heavy."

Variable Back Pressure can not be compensated for by spring adjustments. Therefore, when one or more valves discharge into a common flare header, variable back pressure is placed on the remaining closed valves. This can create a hazardous condition on the remaining closed valves, by adding to the spring force. The valve then is prevented from opening until it has risen far above the vessel design.

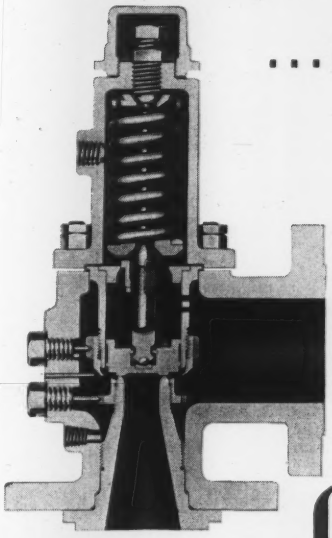
[redacted] is a simple, foolproof method of nullifying these undesirable effects (see Figure 1 above).

Operation — Crosby achieves *Stable Popping Pressure* by the addition of a piston affixed to the spindle, of area proportioned to equal the unbalanced area of the disc (area "A" in Fig. 1). Back pressure introduced through the port in the guide then acts on two equal areas in opposite directions, and cancels itself out, neither loading nor opposing the spring.

To assure full lift and stability, a vent system (see sectional view of piston, Fig. 2) is employed. When the valve is open, the flats on the piston will vent any accumulated back pressure that would tend to close the valve. The adjustment and satisfactory operating characteristics are similar to the conventional valve. The actual flow into the bonnet is relatively low and can be vented to atmosphere, or through a properly sized discharge header.

Extensive, trouble-free use in the field has proved the success of this Crosby Balanced Area Design.

Here's the [redacted] RELIEF VALVE which eliminates back pressure effects ...and reduces costs!



CROSBY RELIEF VALVE
Style JO-BP
with BALANCED AREA DESIGN
for the elimination
of Back Pressure Effects.

Proved ECONOMY!

On the many installations where Crosby JO-BP Valves have been in operation, refineries report sizable savings in piping costs. The reason—smaller discharge lines made possible by higher back pressure. Since Crosby JO-BP Relief Valves will handle back pressure surges ranging up to 90% of inlet pressure, smaller diameter discharge pipe carries the same amount over the same distance that formerly required much larger pipe.

Proved PROTECTION!

On-the-job performance of Crosby JO-BP Relief Valves proves that you can depend on the vented Balanced Design Area to operate at the set pressure. Thus you are assured of a *Stable Popping Point*. What's more, a full lift is obtained over the normal range of back pressures. The Crosby JO-BP operates with an unrestricted nozzle, follows standard nozzle flow equations for above or below critical ratio as the case may be. With its vented Balanced Area Design, the Crosby JO-BP provides a foolproof, time-tested method of eliminating back pressure effects.

CROSBY STEAM GAGE & VALVE COMPANY

43 Kendrick Street, Wrentham, Mass.

District Sales Offices:
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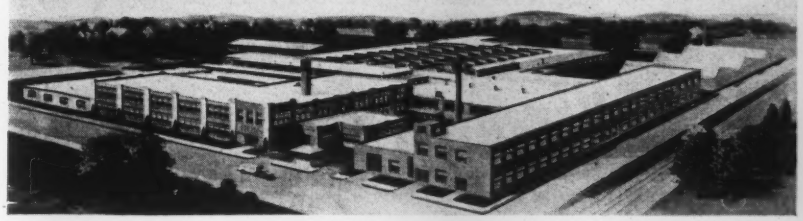
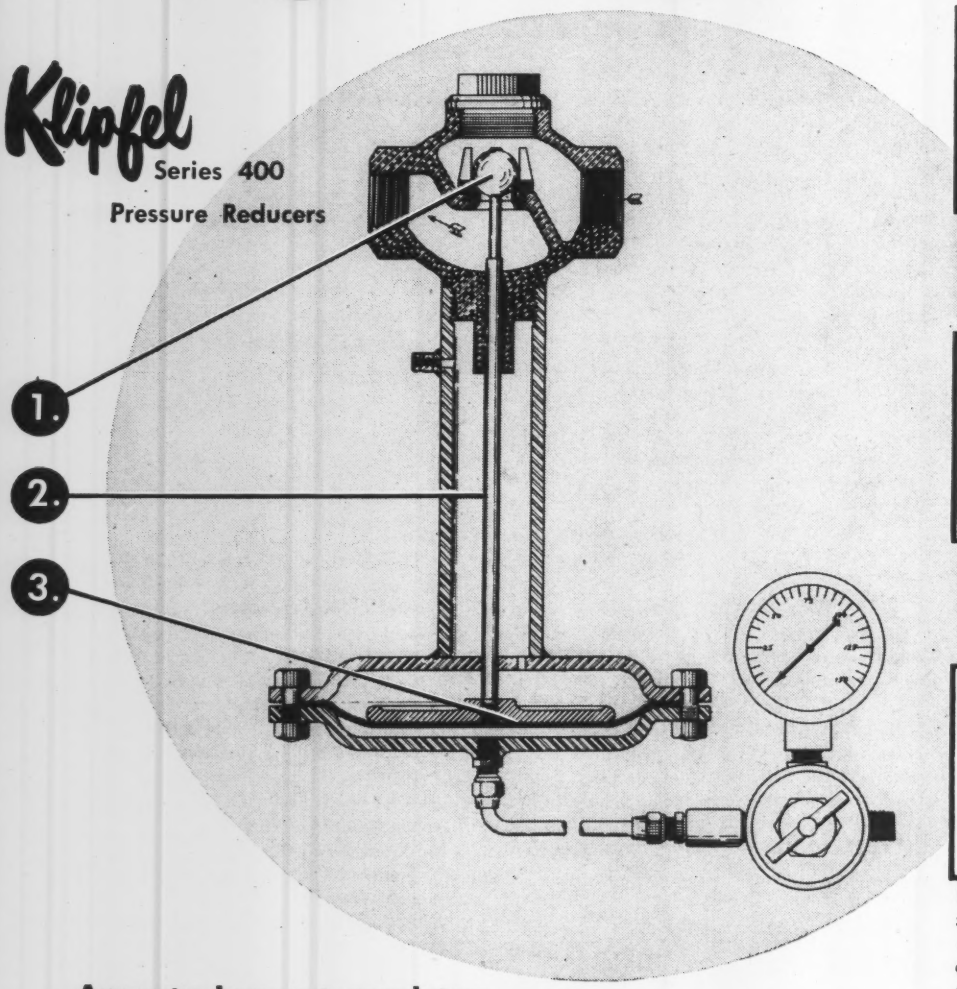
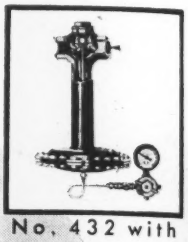


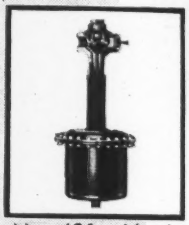
only 3 moving parts

Klipfel Series 400 Pressure Reducers

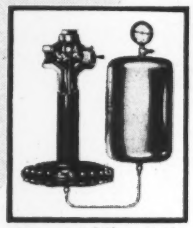




No. 432 with constant air supply—for quick, easy adjustment.



No. 431 with air dome—for isolated installations.



No. 430 with separate air tank—for variable ambient temperature.

Accurate low-cost regulators . . .

FOR longer service with negligible maintenance, operating parts are reduced to just three, inner valve, stem and diaphragm, in the Klipfel 400 Series air-loaded Pressure Reducing Valves. In addition, these 400 Series Valves provide exceptionally close regulation for an unusually low initial cost.

The stainless steel ball inner valve is a perfect sphere, extremely hard and well guided to close to a tight seat. Easily reseated if necessary . . . is self-cleansing and non-sticking. Diaphragm is always in balance . . . no stress, no bursting. Regulation is accurate and easily controlled. For increased safety, flow automatically shuts off in case of diaphragm failure.

For full data on the Klipfel 400 Series Valves, for steam, air, water or gas, write Dept. DA-1 for Bulletin No. 148.

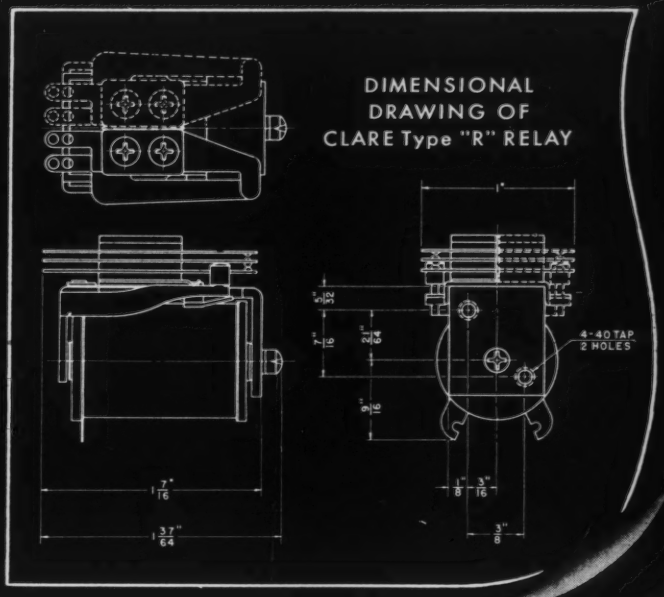
Klipfel VALVES INCORPORATED

DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

A NEW CLARE RELAY...

the Type "R" combines extremely small size with unusual sensitivity and long life

Approximately Actual Size



SPECIFICATIONS

SIZE
Length: 1 3/16"—Height: 1 3/64"—Width: 1"

WEIGHT
Approximately 2 ounces

COIL
Single or double-wound

OPERATING VOLTAGE
Up to 230 volts d-c

ARMATURE
Single or double arm

CONTACT ASSEMBLY
Form A to C. Maximum of 10 springs in each pileup.

MOUNTING
Two #4-40 tapped holes in end of heelpiece

● This new CLARE Type "R" d-c Relay embodies many features of the famous CLARE Type "K" Relay, which was the first to combine the advantages of a telephone-type relay with the small size, light weight and resistance to vibration required to meet the rigid demands of aircraft service.

In appearance, the Type "R" resembles the Type "K", but, through hardly noticeable structural differences, CLARE has given the new Type "R" even greater sensitivity and operating range. Both relays use the same contact springs, but the Type "R" coil is longer and of larger diameter, to provide greater winding space. Life expectancy of the new relay has been not only increased but multiplied.

The CLARE Type "R" Relay retains in an improved form the reed armature suspension which discerning engineers have come to recognize as one of the subtler reasons for the superior performance of CLARE Type "K" Relays over other relays of comparable size and somewhat similar appearance.

The Type "R" is available as either an open or hermetically sealed relay. Clare sales engineers are located in principal cities to give you firsthand information on this new relay and to cooperate with you on any complex relay problem. Call them or write to C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Ltd., Toronto 13. Cable Address: CLARELAY.

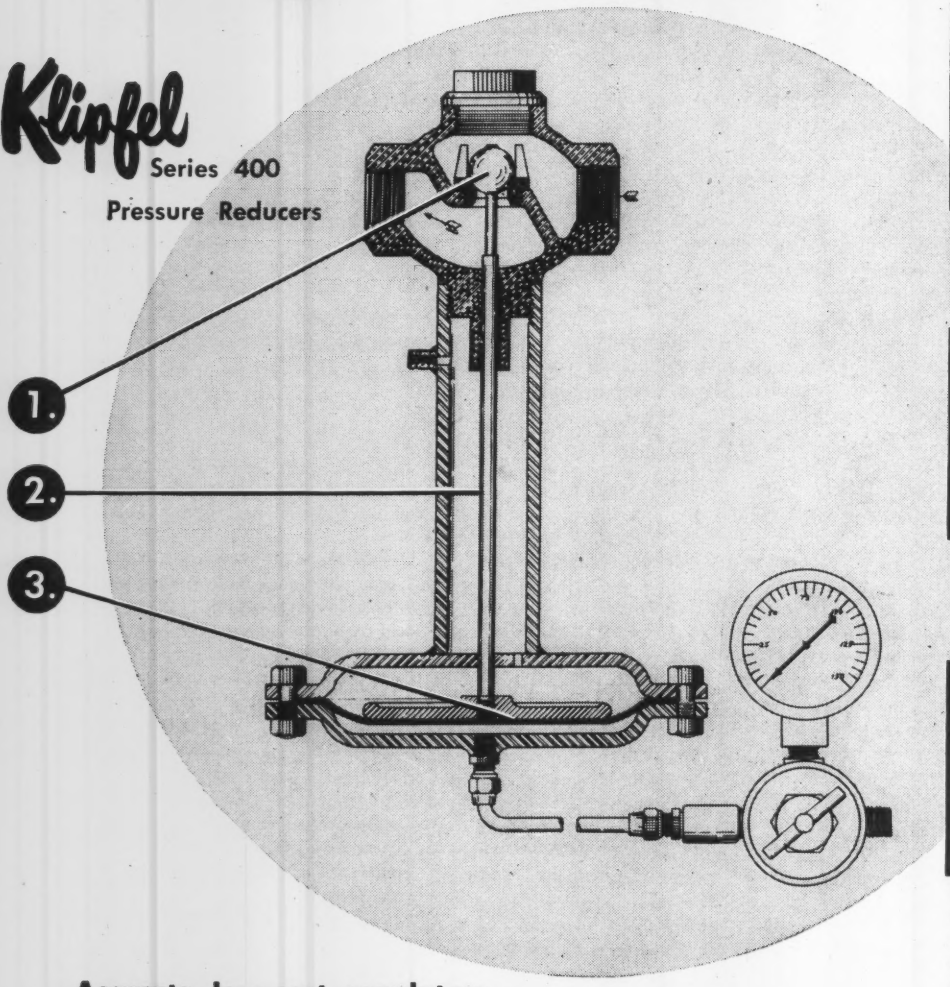
Write for CLARE Bulletin No. 115

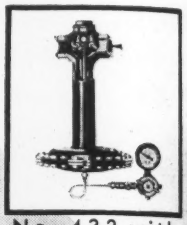
CLARE RELAYS

First in the Industrial Field

only 3 moving parts

Klipfel Series 400 Pressure Reducers





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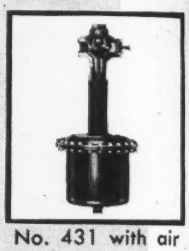

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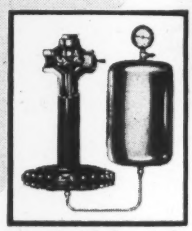

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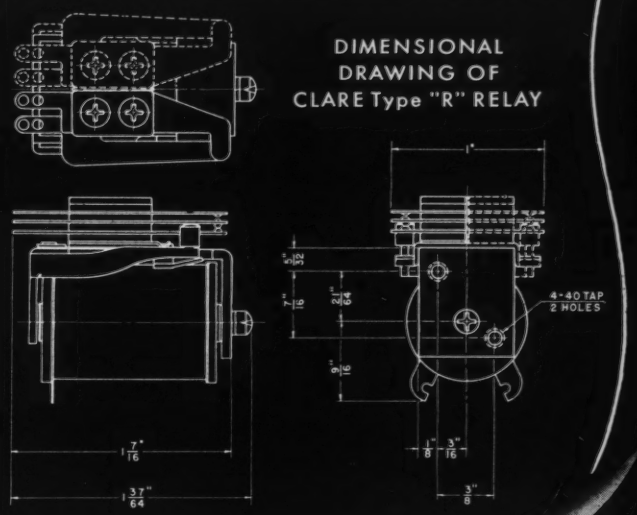
CLARE Type "R" RELAY

Approximately Actual Size

DIMENSIONAL DRAWING OF CLARE Type "R" RELAY



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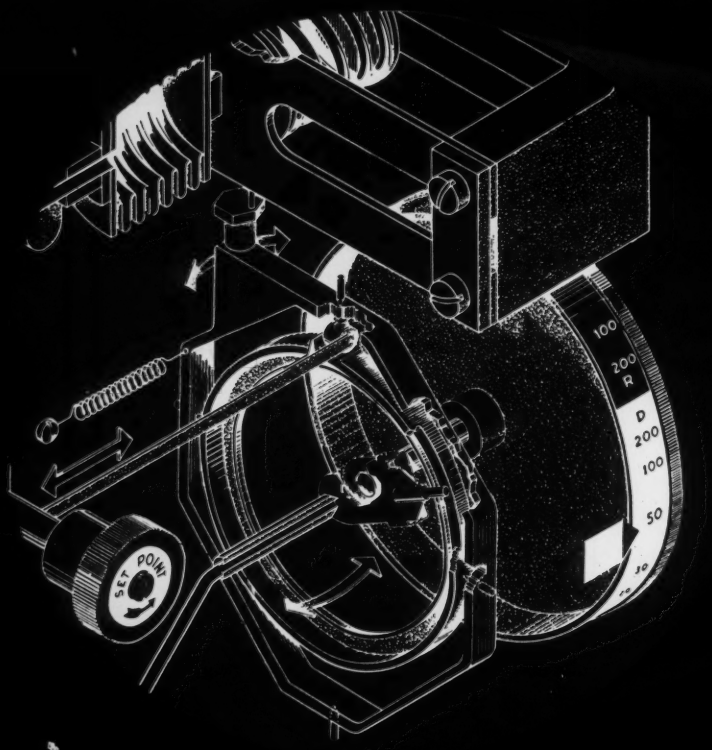
Write for CLARE Bulletin No. 115

CLARE RELAYS

First in the Industrial Field

HERE IS A *Completely*

THE GIMBAL UNIT

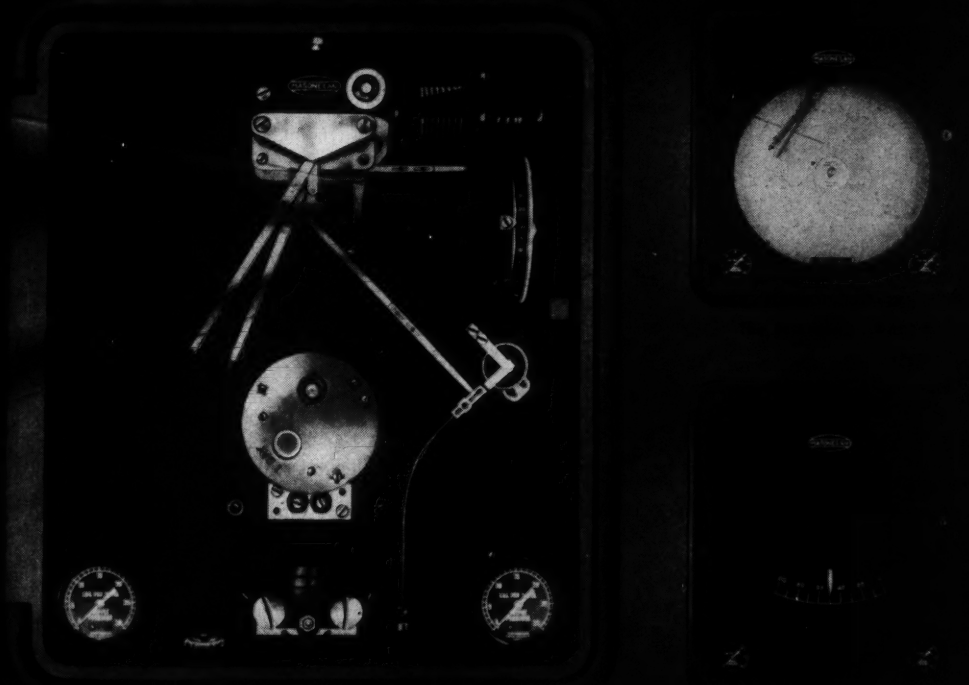


ONE control mechanism gives you **FOUR** combinations of primary and feedback motion to obtain Direct Proportional, Reverse Proportional, Direct Differential-gap and Reverse-Differential-gap Control.

With **ONE SETTING** you select type of control, type of action and proportional band or differential-gap setting.

A HIGH C_Q PRODUCT

New CONTROLLER



MODELS NOW AVAILABLE

Recording and indicating types are now available for pressure, temperature, liquid level or flow service with the following types of control:

Proportional (includes Differential-gap and On-Off)

Proportional-Reset

Plus these supplementary types—

Pneumatic Set — for remote setting of control point

Time Cycle — features cam drive independent of chart drive.

Differential — maintains positive or negative differential between two variables — to 50% of chart range.

Also available are Recorders, Transmitters, and Manual Control subpanel with four-position transfer switch.

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R-S valvEvents

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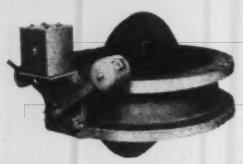
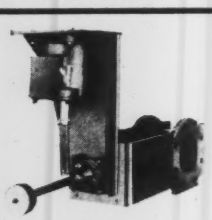
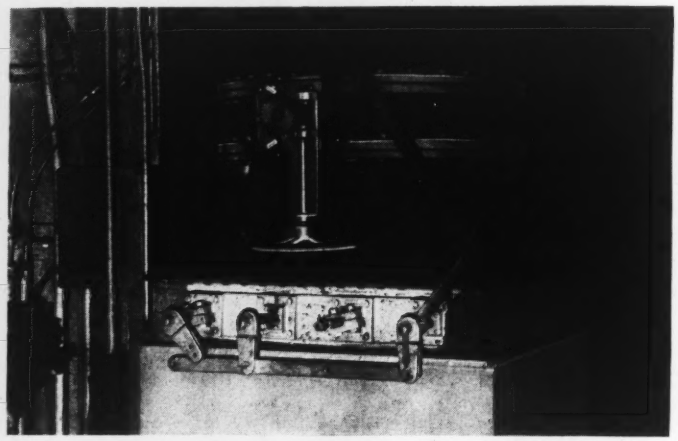


EMERGENCY OIL SERVICE—No. 628—solenoid trip valve. Should the solenoid function, the latch is tripped which causes the counter-weight to open or close the valve by gravity. Available in any metal or alloy and in various sizes for emergency shut-off or vent for air, gas, steam, oil, and water.



700° F. EXHAUST GAS SERVICE—No. 826—6-inch 125-pound R-S "H" metal valve used on small turbine generator. Equipped with 18—8 shafts, hastelloy bushings, finned lubricated stuffing box and solenoid trip mechanism.

STEAM SERVICE—No. 677—1500-pound welding end steel valve for superheated steam—A. S. M. E. Standards.



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Control and Shut Off Practically Any Material

The beveled vane seats firmly at a 12½° angle and is closed from a fully open position through 77½° of arc by either manual or automatic operation. A metal-to-metal seat gives satisfactory commercial shut-off. When required, Monel or stainless steel can be welded to the vane periphery and a babbitted seat used in the valve body. Drip tight or bubble tight closure can be obtained with a rubber seat.

Power controlled prime movers delivering the necessary foot pounds of torque open or close these self-cleaning valves at any desired speed from one second to eight minutes according to requirements. Pressures range from 2 to 2500 psig and temperatures from minus 300° F. to plus 2000° F.

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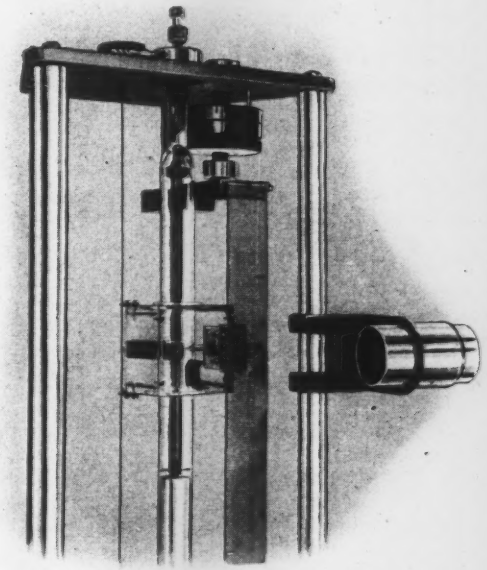
introducing

THE W&T PRECISION CALIBRATING STANDARD

The new W&T Precision Calibrating Standard offers an accurate and convenient means for measuring either absolute or differential pressure. Consisting of a mercury column designed for convenient bench mounting it provides a custom calibrated range of 800 mm. Hg. in any desired units. For precision calibrations, readings to 0.01 mm. mercury with an accuracy of 1 part in 5000 are made possible by a unique magnetic vernier. Dependable and consistent results allow for its use in the calibration of such pressure sensitive instruments as aircraft altimeters, surveying altimeters, meteorological barometers, laboratory barometers and for absolute pressure elements having a controlling or telemetering function.



Outstanding features of the W&T Precision Calibrating Standard include:

Range of Absolute or Differential Pressure: 0 to 800 mm. Hg. by 1 mm. or any other units

Magnetic Vernier Graduation: One-tenth scale graduation

Accuracy: 1 part in 5000

Built-in Thermometer

Temperature and gravity compensated scale

Full-range indication

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Meniscus reading eliminated

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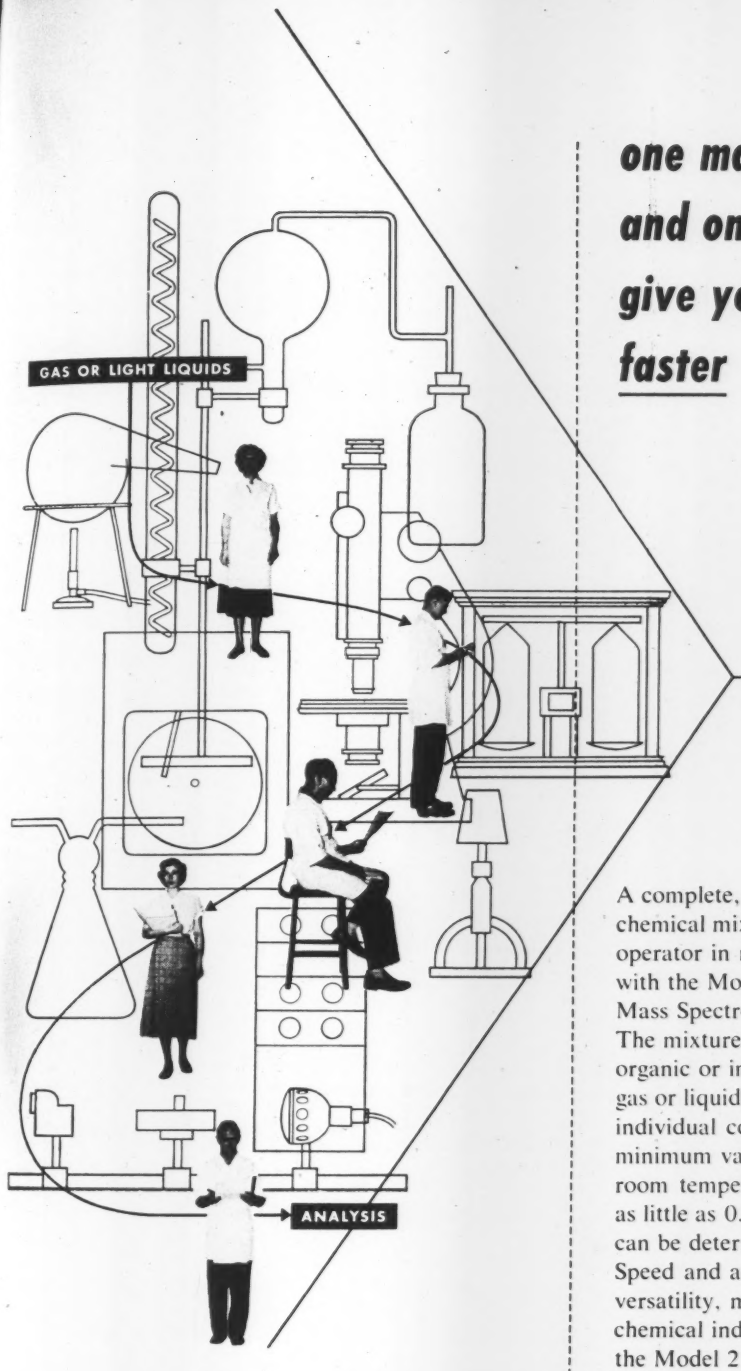
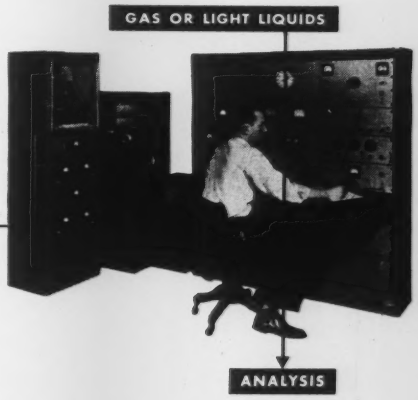
BROWN INSTRUMENTS
First in Controls

• *Important Reference Data*

WRITE FOR CATALOG 200-2 ON THERMOCOUPLE WELLS . . . AND FOR NEW PYROMETER SUPPLIES BUYERS' GUIDE NO. 100-4.



one man and one instrument give you better answers faster



A complete, accurate analysis of a complex chemical mixture can now be made by one operator in minutes instead of hours or even days with the Model 21-103 Consolidated Mass Spectrometer.

The mixture being analyzed may be composed of organic or inorganic compounds. Virtually any gas or liquid sample may be handled so long as the individual components in the mixture exert a minimum vapor pressure of 250 microns at room temperature. Trace impurities constituting as little as 0.001 mole per cent of the mixture can be determined.

Speed and accuracy of analysis, together with versatility, make this the ideal instrument for the chemical industry. For further information on the Model 21-103, write for Bulletin CEC-1800B.

consolidated engineering corporation

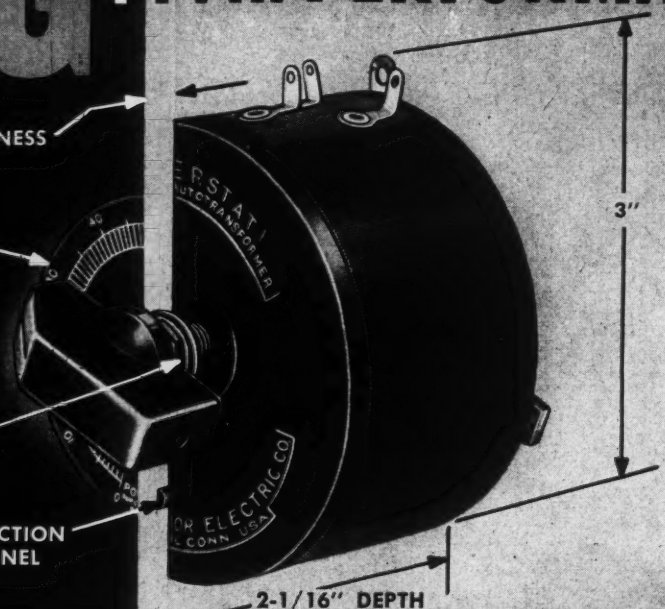
Analytical Instruments for Science and Industry

300 No. Sierra Madre Villa
Pasadena 8, California

analytical mass spectrometer

analytical service—*analysis by mass spectrometry is offered to those whose quantity of samples does not justify the purchase of an instrument. For costs, handling of samples and other details, write for Consolidated's Analytical Service Bulletin.*

SMALL . . . IN SIZE
BIG . . . in PERFORMANCE



TYPE 10 POWERSTAT
VARIABLE TRANSFORMER

RATED:

INPUT: 120 Volts, 60 Cycles
1 Phase

OUTPUT: 0 - 120/132 Volts,
1.25 Amperes
150/165 VA

APPLICATIONS

of POWERSTAT Type 10 are as innumerable as is the need for a variable a-c voltage control in today's low wattage electric and electronic equipment. It is ideal as the variable a-c voltage component in electronic tube testers; low wattage power supplies and rectifiers; low wattage heaters, furnaces, plastic molding equipment . . . and in any a-c voltage application where 50, 100 and 150 watt rheostats are now being employed.

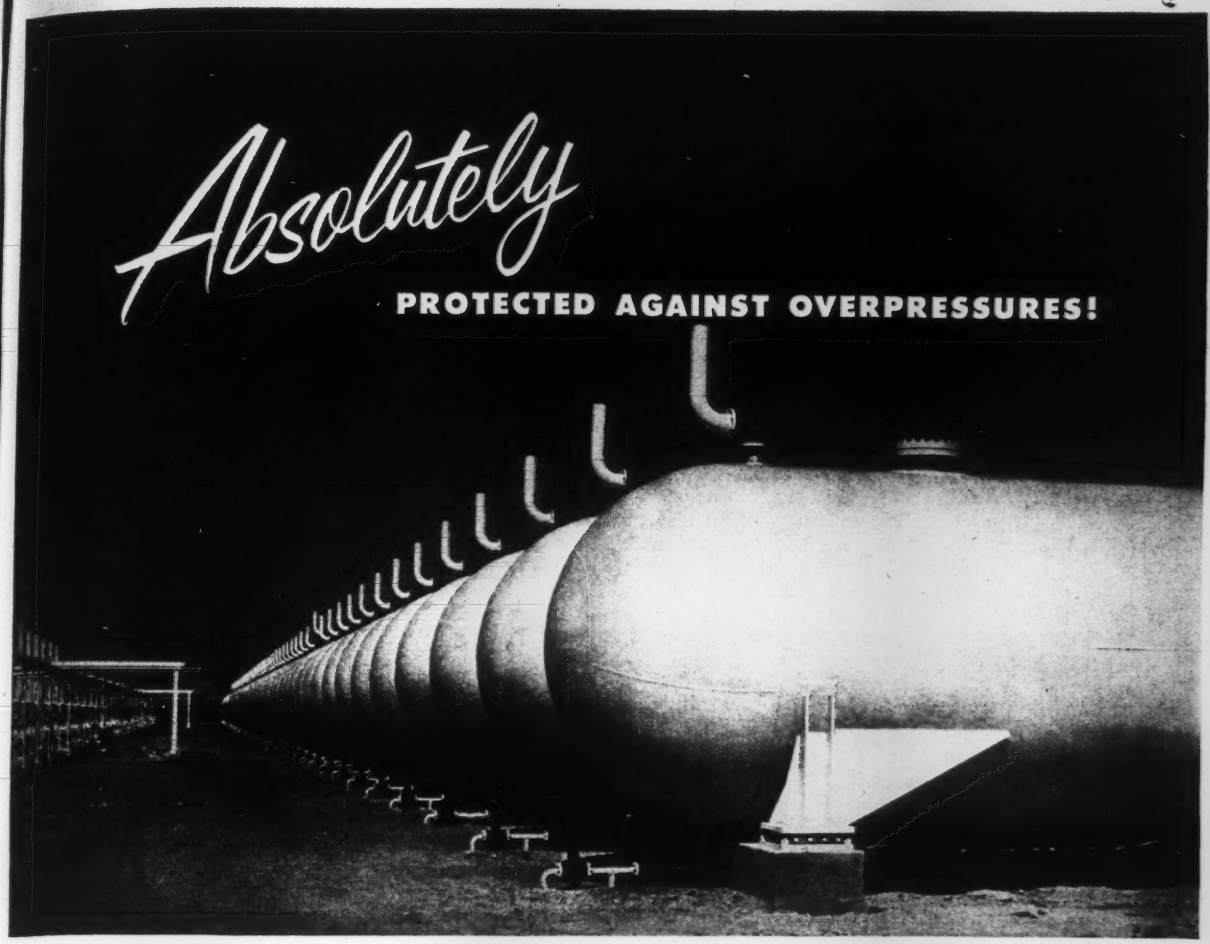
A COMPACT VARIABLE A-C VOLTAGE CONTROL FOR LOW WATTAGE APPLICATIONS

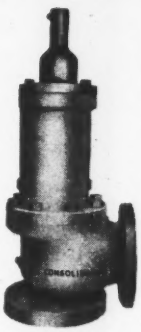
To date, the many low wattage (50 . . . 100 . . . 150 watts) applications requiring variable a-c voltage control have had to be content with the inefficient, heat dissipating rheostats and other resistance types of control. With the introduction of the new POWERSTAT Type 10, the many advantages of POWERSTAT variable transformers are available for these low wattage requirements. A continuously adjustable output voltage from 0 to 120 or 132 volts is at the fingertips to control loads up to 165 VA. Type 10 does not have to be tailored to the load — it will deliver a variable voltage to any load up to its capacity. Type 10 is highly efficient — *does not* control by dissipating power in the wasteful form of heat. Other features: glass smooth commutator surface . . . advanced winding technique . . . superior core and coil design . . . rugged construction . . . single hole mounting . . . can be installed under a 3" chassis saving valuable space.

For additional information on the new, compact POWERSTAT Type 10, send for Bulletin P252.

Write to: 703 Thure Avenue, Bristol Connecticut

THE SUPERIOR ELECTRIC CO.
BRISTOL, CONNECTICUT





Uncontrolled pressures in processing equipment invite disaster. That's why so many unfired pressure vessels—gas, vapor and liquid storage tanks, pipelines, pumps—are protected by Consolidated Safety Relief Valves.

Dependable tightness is foremost in valve safety standards. Consolidated Safety Relief Valves don't leak under discharge piping stresses because outside bevel seat and floating guide construction permit the disc to be moved on a radial seating surface. Tightness is absolute in all positions within the deflection range. Continuously reliable performance at the rated capacity safeguard life, property and production, even in the severest service.

Consolidated Safety Relief Valves are widely used for another basic reason: *simple design.* With 25% fewer parts than ordinary safety relief valves, service and standardization problems are reduced, maintenance costs are cut. Get all the facts first hand. See your local Consolidated Distributor.

1879 CONSOLIDATED U.S.A.

CONSOLIDATED SAFETY RELIEF VALVES

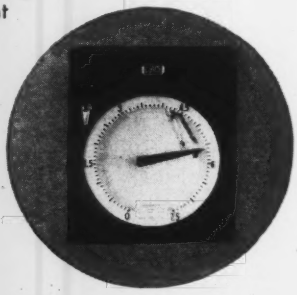
A product of **MANNING, MAXWELL & MOORE, INC.** TULSA, OKLAHOMA

MAKERS OF 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'HANCOCK' VALVES, 'ASHCROFT' GAUGES. BUILDERS OF "SHAW-BOX" CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.

Measures fundamental indicator of combustion efficiency—Oxygen. Applicable to power plants and process problems like catalytic crackers, open hearths, process heaters, inert gases, etc.

PRINCIPLE — Based on paramagnetic (attracted by magnetism) properties of Oxygen.

FEATURES — Highly sensitive to change in O_2 content — responds rapidly. Electrically operated. Electronic type recorder. Temperature controlled. Pressure compensated. No liquid or gaseous fuel required. No chemicals. Highly accurate. Not affected by wide change of gas flow rate. Continuous sampling and recording. Glass and corrosive resistant sampling system. Remote mounted analyzer and recorder. Four records on same chart possible. Low maintenance.

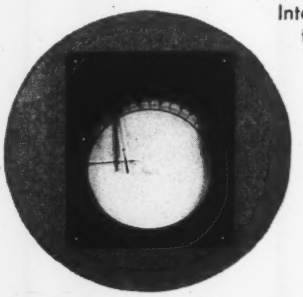


Hays Magnotherm O_2 Meter

Provides a *QUANTITATIVE* guide to efficiency — deals with quantities of air and steam; by contrast CO_2 and O_2 meters are *QUALITATIVE* guides since they determine directly quality of combustion gases.

PRINCIPLE — Record of steam flow is assumed to be Btu's produced; record of air flow is calibrated to flow of air required to generate that steam.

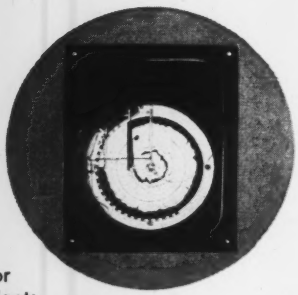
FEATURES — Electric operation of flow meter and air flow recorder. Diaphragm-type air flow measuring unit. Air flow measuring element does no work. Air flow recorder—motor operated. Adjustable cam air flow calibration. Mercury transmitter — pressures to 2500 psi. Interchangeable range tubes for steam flow. Remote mounted steam flow transmitter. No high pressure piping into panel. Easily installed and adjusted. Low maintenance.



Hays-Penn Boiler Efficiency Meter

Which combustion guide is best?

IT DEPENDS . . . on the fuel you're burning, the accuracy you require, the price you want to pay, etc. Your particular needs will determine your choice . . . but remember—only Hays can supply you *without bias* . . . because only Hays has a *complete* line of Combustion Guides.

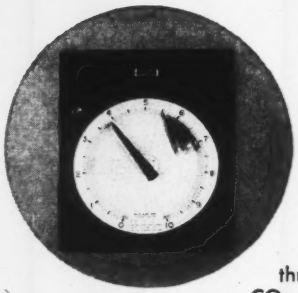


Hays Combustion Meter

Hundreds of these meters have been in operation for many years in all types of plants burning all kinds of fuels and saving thousands of fuel dollars.

PRINCIPLE — Operates on Orsat principle of volumetric measurement and chemical absorption. Difference in sample before and after absorption gives exact percentage of CO_2 absorbed by chemical.

FEATURES — Low price. Water operation. Pressure and temperature compensated. Volumetric determination. Chemical absorption. 2-minute operating cycle. Easily understood. Rugged construction. Low maintenance. Available in 6 remote mounted types and 3 integral types: (a) CO_2 only—recording with or without indicator (b) CO_2 and flue gas temp. recorder combined (c) CO_2, draft or flue gas temp. recorder combined. Remote or integral mounting.



Hays Condu-Therm CO_2 Meter

A *new* instrument using three *established* ideas: (1) CO_2 as guide to combustion efficiency (2) thermal conductivity principle (3) electronic type operation.

PRINCIPLE — Based on thermal conductivity of gases, i.e., that all gases conduct heat at different rates.

FEATURES — 5-second response to change in CO_2 content. $\pm$ .25% accuracy for ranges 0 to 20%. Electrically operated. Electronic type recorder. Temperature controlled. Humidity controlled. No chemicals required. No moving parts in analyzer. Continuous sampling. No drying agent required. Unmatched construction features. Not affected by wide change in gas flow rate. High sensitivity. Rapid response Continuous recording. Remote mounted analyzer and recorder. Low maintenance.

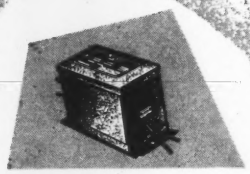
THE HAYS CORPORATION

MICHIGAN CITY 8, INDIANA

Automatic Combustion Control • Boiler Panels • Hays-Penn Flowmeters
Veriflow Meters and Veritrol • Gas Analyzers • Draft Gages
Combustion Test Sets • CO_2 Recorders • Electronic Oxygen Recorders

WIDEST

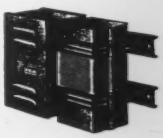
range of voltage regulator ratings and types available from stock



STANDARD TYPE "CV" UNITS:
15 VA to 10,000 VA

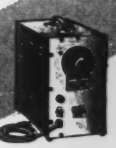
Most voltage regulating requirements can be met from these "stock" voltage regulating transformers. Regulation is ±1% or less with a total primary voltage variation as great as 30%. This is the static-magnetic voltage regulator that has become the "Standard of the World."

STANDARD SPECIALIZED TYPES:
Available from regular production stock:



... less than 3% harmonic distortion ... ±1% regulation.

... ±3% regulation or less... single, compact voltage source.

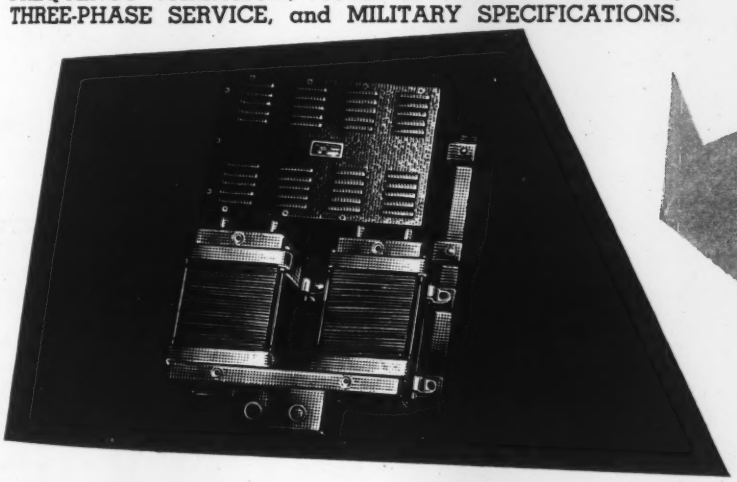


... less than 3% harmonic distortion ... ±1% regulation.

... ±3% regulation ... inexpensive ... plug-in type.

CUSTOM DESIGNED UNITS: 1 VA to 25,000 VA

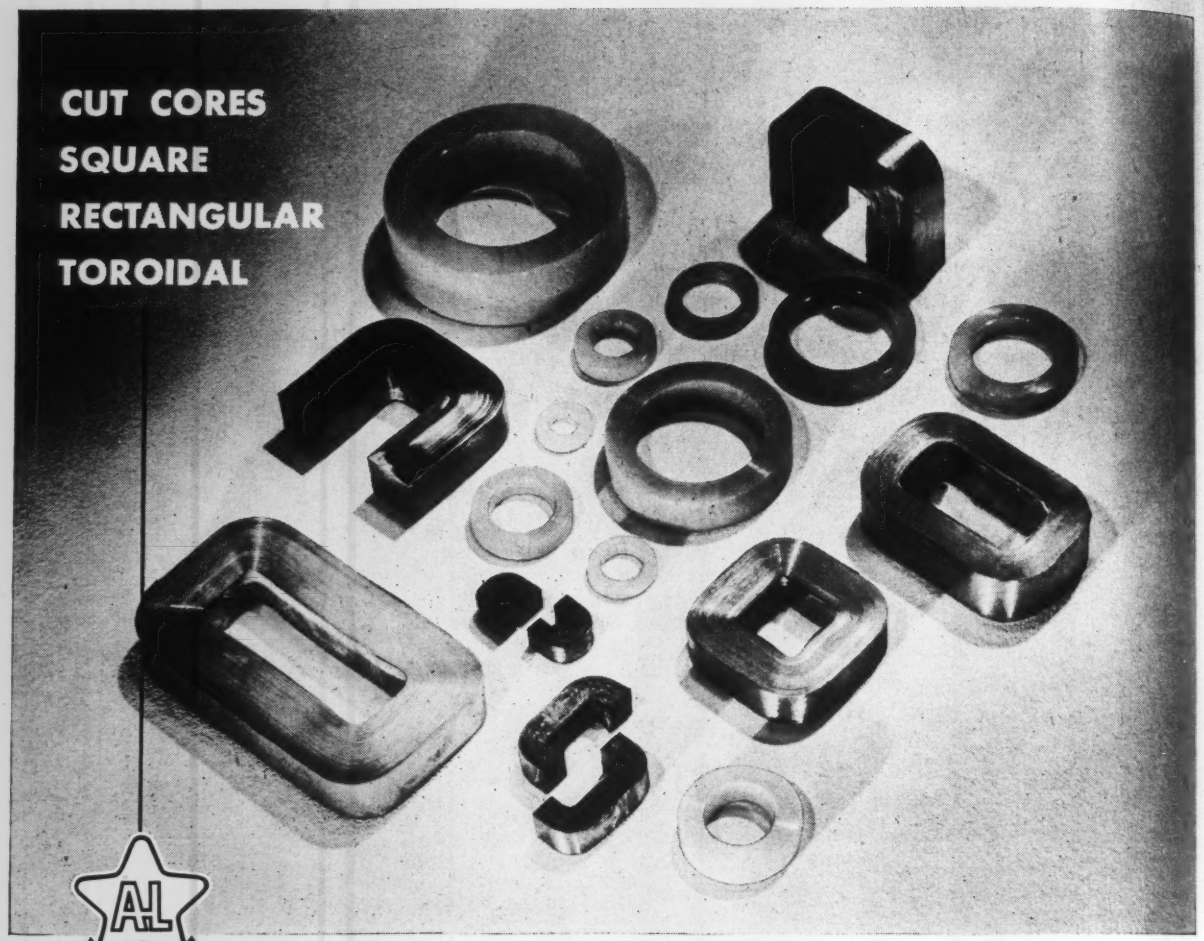
The wide flexibility of the SOLA Constant Voltage principle makes possible special designs to meet your specific requirements. Often, time and money can be saved by direct use or modification of a regulator from the several hundred special designs on file. Custom designs can include: SPECIAL VOLTAGE RATIOS, SPECIAL FREQUENCIES, COMPENSATION FOR FREQUENCY VARIATION, MULTIPLE OUTPUT VOLTAGES, THREE-PHASE SERVICE, and MILITARY SPECIFICATIONS.



New Catalog...

Write on your letterhead for our new Constant Voltage Catalog. It gives complete specifications, and operating data on SOLA Constant Voltage Transformers, including special units. Request Bulletin CV-142.

SOLA *Constant Voltage* **TRANSFORMERS**



Anything You May Need in TAPE-WOUND CORES

RANGE OF MATERIALS

Depending upon the specific properties required by the application, Arnold Tape-Wound Cores are available made of DELTAMAX . . . 4-79 MO-PERMALLOY . . . SUPERMALLOY . . . MUMETAL . . . 4750 ELECTRICAL METAL . . . or SELECTRON (grain-oriented silicon steel).

RANGE OF SIZES

Practically any size Tape-Wound Core can be supplied, from a fraction of a gram to several hundred pounds in weight. Toroidal cores are available in fifteen standard sizes with protective nylon cases. Special sizes of toroidal cores—and all cut cores, square or rectangular cores—are manufactured to meet your individual requirements.

RANGE OF TYPES

In each of the magnetic materials named, Arnold Tape-Wound Cores are produced in the following standard tape thicknesses: .012″, .008″, .004″, .002″, .001″, .0005″, or .00025″, as required.

Applications

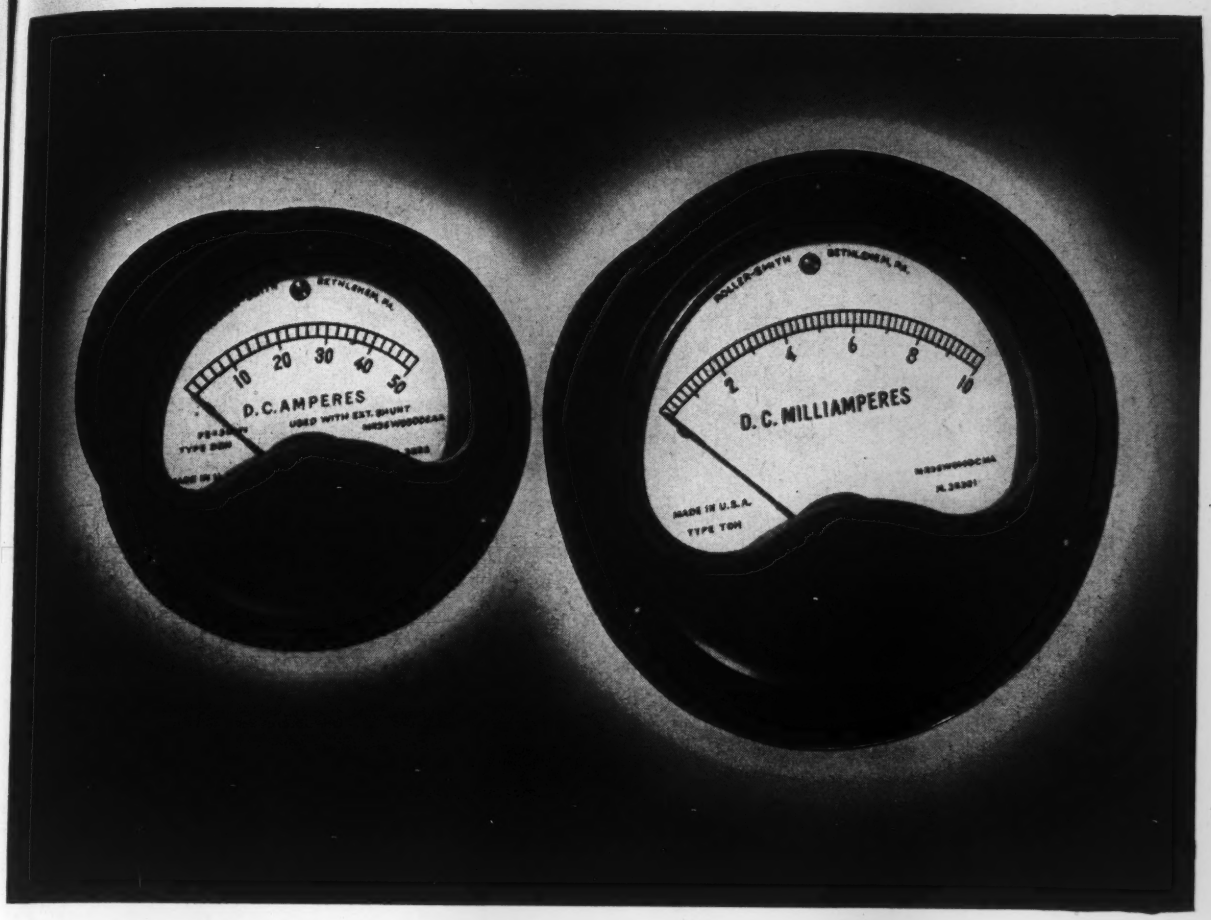
MAGNETIC AMPLIFIERS
PULSE TRANSFORMERS
CURRENT TRANSFORMERS
WIDE-BAND TRANSFORMERS
NON-LINEAR RETARD COILS
PEAKING STRIPS . . . REACTORS.

WAD 3983

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois



Roller-Smith
Ruggedized Instruments

Shock-Proof • Vibration-Proof • Weather-Proof

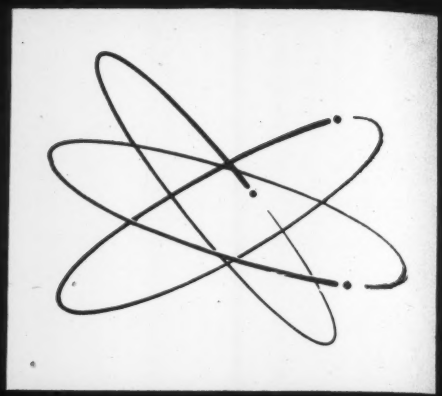
Roller-Smith announces production of hermetically sealed *Ruggedized* 2½" and 3½" instruments conforming to MIL-M-10304.

In addition to *Ruggedized* instruments, a complete line of hermetically sealed and unsealed types in conformance with Government specifications are available.

ROLLER SMITH

ROLLER-SMITH CORPORATION
BETHLEHEM, PENNSYLVANIA

instantaneous *all-electronic control*

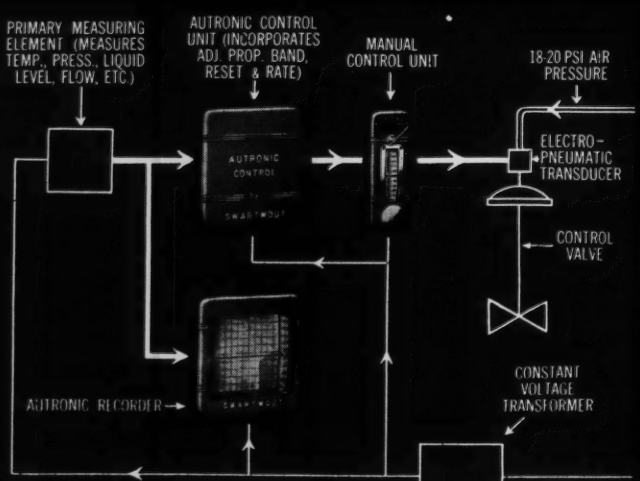


of pressure

temperature

flow

and level . . .


PRIMARY MEASURING ELEMENT (MEASURES TEMP., PRESS., LIQUID LEVEL, FLOW, ETC.)
AUTRONIC CONTROL UNIT (INCORPORATES ADJ. PROP. BAND, RESET & RATE)
MANUAL CONTROL UNIT
18-20 PSI AIR PRESSURE
ELECTRO-PNEUMATIC TRANSDUCER
CONTROL VALVE
AUTRONIC RECORDER
CONSTANT VOLTAGE TRANSFORMER
115V 60~ AC POWER
POWER LINE

The new Swartwout Autronic Control System brings new speed, new accuracy to your process controls. Without mechanical motion of any kind this new *all-electronic control system* spans distance between primary element and control element *without interval.* Measuring . . . analyzing . . . correcting —the Autronic System keeps your process on stream . . . assures quality product by controlling pressure, temperature, flow and level properly, instantaneously *without cycling, drifting, shifting.* Call in our engineering representative to explain how Swartwout Autronic Controls will bring new accuracy to *your* process and power instrumentation and control. Or write *today* for literature on the new Swartwout Autronic Control System.

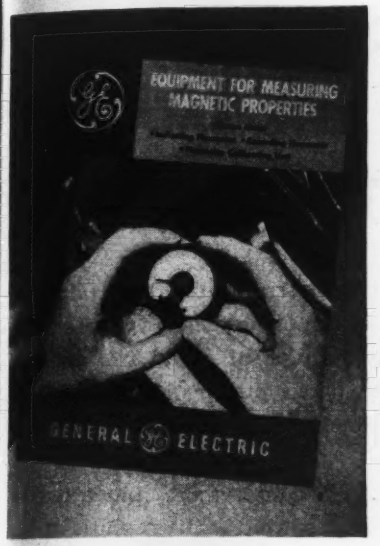
A-4878

Swartwout *Autronic* CONTROL SYSTEM

THE SWARTWOUT COMPANY • 18511 EUCLID AVENUE • CLEVELAND 12, OHIO

INSTRUMENTS FOR LABORATORIES

New G-E Twelve-page Bulletin Describes Complete Magnetic Measuring Equipment



General Electric's new bulletin, "Equipment for Measuring Magnetic Properties," is just off the press. The bulletin describes the Gauss Meter and Fluxmeter (also featured in application stories on this page) in addition to the Recording Fluxmeter and Fluxmeter Calibration Unit. Check the coupon for your copy.

RECORDING FLUXMETER

The G-E photoelectric recording fluxmeter consists of a Type CE photoelectric recorder that uses a fluxmeter galvanometer for recording magnetic flux changes in a search coil by automatically following and recording the deflections of the fluxmeter. This fluxmeter will indicate flux linkages from 3300 to 106,000 per chart division.

FLUXMETER CALIBRATING UNIT

The G-E fluxmeter calibrating unit can be used with both the indicating fluxmeter and the recording fluxmeter to facilitate calibration.

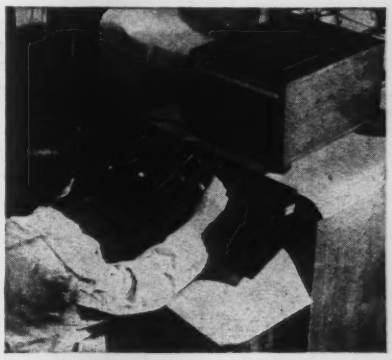
Dings Magnetic Separator Recommends G-E Gauss Meter

Dings Magnetic Separator Co., Milwaukee, Wis., manufacturer of magnetic separators, recommends the G-E gauss meter for determining the strength of the horseshoe magnets used in their separators. Reports Mr. Karl A. Blind, Chief Engineer at Dings, "We are recommending the G-E gauss meter to operating personnel in plants where magnetic separators are an essential part of production machinery. We believe operators should acquire and use the gauss meter for purposes of effectively and rapidly checking the full operating efficiency of the magnet."

MAINTAINS CLOSE LIMITS

Magnetic separators consist of either one or a series of permanent or electromagnets. Materials which contain magnetic foreign particles are passed in a steady flow near the magnets—which remove these foreign particles. This process sometimes requires much repetition, with the strength of the magnets varied each time. In order to do this, the exact strength of each magnet has to be controlled to within narrow limits. The General Electric gauss meter enables operators to maintain these limits.

Designed for unidirectional fluxes, the gauss meter can be used for checking flux densities and flux gradients in air gaps, and for measuring flux density in iron structures.



Magnets Balanced Quickly With Indicating Fluxmeter

Wilfred O. White and Sons, Inc., Boston, Massachusetts, manufacturers of the famous Constellation spherical compass and other navigational instruments and associated equipment, are now using a General Electric indicating fluxmeter for checking the flux-density balance of permanent magnets used in their complete range of compasses.

IMMEDIATE INDICATION GIVEN

The raw magnets are inserted in holes in a testing panel connected to the fluxmeter, and especially designed for this application. The fluxmeter gives an immediate and accurate indication of their comparative strength. If one magnet is too strong, it is inserted into the "demagnetizer," another hole in the panel. The process is repeated until the desired balance is obtained.

With this system, the flux densities of the magnets can be brought to within 10 percent of each other, a high degree of balance for magnets of this type.

SECTION B605-10, GENERAL ELECTRIC
SCHENECTADY 5, N. Y.

Please send me the following bulletin:

Indicate:

√ for reference only

× for planning on immediate project

☐ GEC-777, G-E Equipment for Measurement of Magnetic Properties.

NAME.....

COMPANY.....

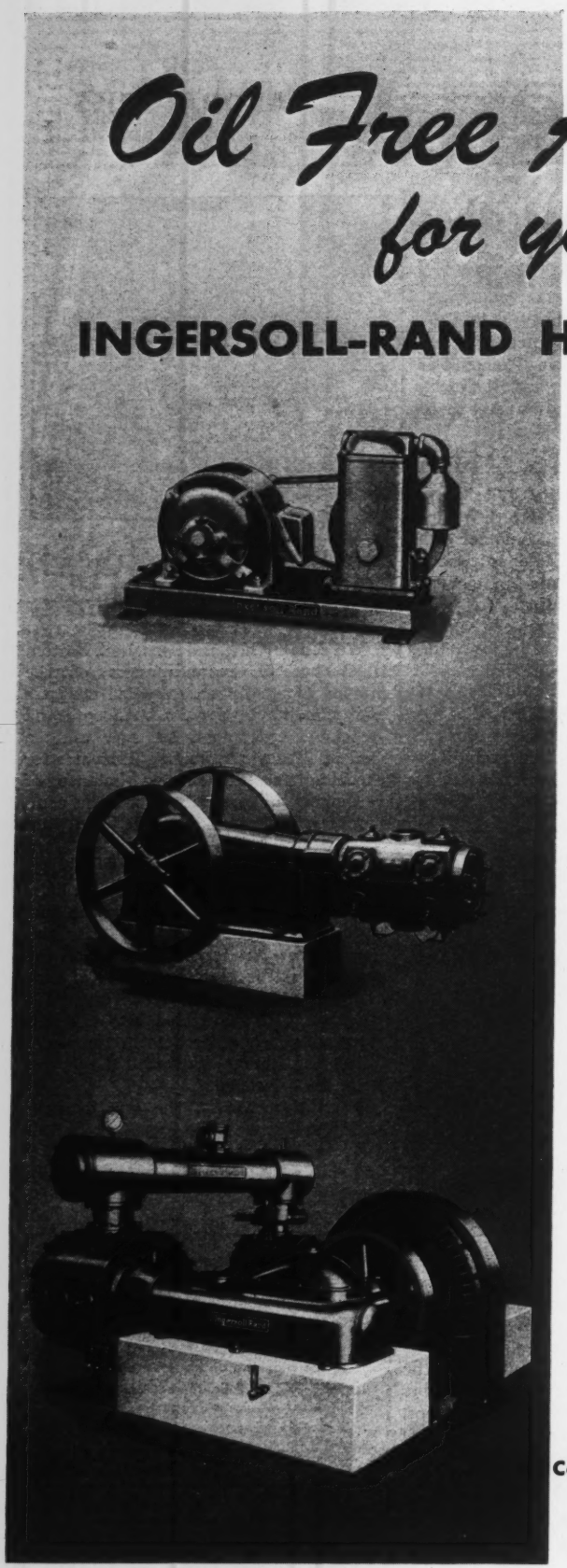
STREET.....

CITY.....ZONE.....STATE.....

GENERAL ELECTRIC

Oil Free Air for your Instruments

INGERSOLL-RAND HAS NL COMPRESSORS FROM THE SMALLEST TO THE LARGEST



Air-operated instruments, like production tools, are vitally important. That's why so many plants are using Ingersoll-Rand NL air compressors, that *don't pump oil*. This guards against instrument failures caused by oil-laden air.

Non-lubricated compressors, pioneered by I-R, feature pistons fitted with graphitic-carbon rings that prevent metallic contact of the piston with the cylinder bore. These carbon rings are segmental with metallic inner expanding rings, to give the proper wall pressure. Because metallic contact is eliminated, and the rings are self-lubricating, the Ingersoll-Rand NL Compressor cylinders require no lubricant.

To really put an end to production delays and excessive maintenance costs caused by oil-clogged instruments, get all the engineering facts and figures I-R makes available. Simply contact your nearest I-R representative, or write direct to Ingersoll-Rand, 11 Broadway, New York 4, New York.

Model N machines available through 1 hp.

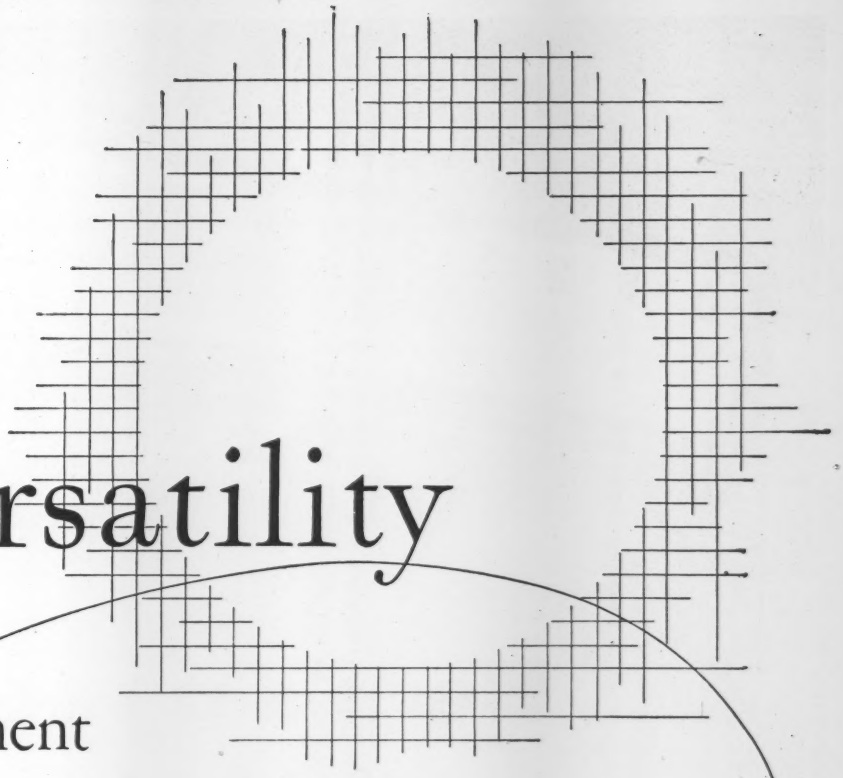
Model 235 HNL machines available through 3 hp—other models through 250 hp.

Ingersoll-Rand

717-3

Compressors . . . 70 years of compressor "know-how" packed into these new compressors for air operated instruments!

COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO BLOWERS • CONDENSERS • CENTRIFUGAL PUMPS • DIESEL AND GAS ENGINES



for Versatility in force measurement

HAGAN THRUSTORQ

Whenever you have a force measuring problem—consider Hagan THRUSTORQ. This partial list of applications now being handled successfully by this simple and accurate device will give you some idea of its possibilities.

- cradle dynamometer measurement of airplane and automobile engines
- single cylinder engine test stands
- evaluating turbine blade shapes
- measuring torque of helicopter engines
- automatic batch weighing
- measuring thrust of jet engines and rockets
- testing piston rings
- chassis dynamometers
- axle testing machines

If you think Hagan THRUSTORQ may be the answer to some of your problems, write us about it. Our engineers are at your service.

HAGAN CORPORATION, HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA

HAGAN HALL BUROMIN CALGON

HAGAN THRUSTORQ
measuring thrust and torque *with air!*

Here's a record...

that few have ever seen!

Ninety-nine out of 100 metallurgists and heat-treaters have not yet had a chance to see a continuous instrument record of the carbon in a furnace's carburizing gas. And probably not 99 out of 10,000 production men have seen such a sight.

But neither group is going to be unfamiliar with this advance for much longer, because this valuable information is now as easy to get as a temperature record. It comes from a Micromax Carbon Recorder, which is part of the brand new L&N Microcarb Control.

Already several dozen plants have ordered Microcarb equipment. Here and there a present user is letting his friends drop in for a peek. So, the Carbon Record will soon be pretty generally known to men who look for the modern way to cut carburizing costs or improve carburized parts.

Every metallurgist and heat-treater will probably have his own idea as to exactly what this instrument can mean in his plant. Technically, it shows only the percent of active carbon in the atmosphere of a Homocarb Furnace; but practically, it shows the surface carbon content of the parts being carburized! Used with Microcarb Control, it means that "the carbon you set is the carbon you get." You can control the surface carbon, regardless of whether you want a shallow or deep case; on familiar steels or the newer alloys.

Only Homocarb carburizing equipment of our new Series H can be used with Microcarb, because the furnace and its temperature control must be designed to meet the needs of atmosphere regulation. Specific features are a soundly designed electric furnace with solid-bottom retort, improved fan housing and work support, and aerodynamically designed discharge jets. Micromax temperature control of the Duration-Adjusting Type is included.

The full Microcarb story will be mailed on request. Address either our nearest office, or 4955 Stenton Ave., Philadelphia 44, Pa.

LEEDS NORTHRUP

Ind. Ad. TD4-623(6)

Editorial Comment

Frontiers of Instrumentation

DESPITE talk of "manless factories" and "robot machines" the modern frontier of instrumentation—the region of unsolved problems—is more immediate and less spectacular. The manless factory and robot machine are here today. All the problems associated with robotizing a lathe or automatizing a distillation tower are solvable with existing instruments. The as-yet-unsolved problems involve the dollars-and-cents factors of applicability.

Dr. Donald P. Campbell, Associate Professor, Electrical Engineering, M.I.T., spoke on this subject to a joint meeting of the American Institute of Electrical Engineers (Pittsburgh Section) and the Engineers' Society of Western Pennsylvania (Electrical Section). The meeting was held at the Mellon Institute Auditorium, Pittsburgh, Pa., on February 18, 1952. In his address, Dr. Campbell outlined the difficulties involved in analyzing the process response characteristics—the first unknown in any industrial control application. This is particularly true of processes in continuous operation; two hours' loss of production can amount to many thousands of dollars' loss of product.

Thus the first major problem is analysis of the process in terms of frequency and phase response. A much-to-be-hoped-for development would be a method for deriving the plant characteristics from operating data.

A second major problem involves the analytical handling of nonlinear responses. Although linear responses of almost any shape can be matched and handled by instruments, the nonlinear response (a too familiar one in industry) is at present not handled without major assumptions and limitations that, in effect, ascribe a degree of linearity to the system.

A third problem involves the calculation of flow, temperature, pressure, etc., in systems with distributed parameters. Here again, the conventional analysis based on lumped parameters is not valid.

A fourth problem involves the specifications of instruments. For reasons known only to the manufacturers, the response of their instruments is not public knowledge. This information is necessary because the instrument must be at least one decade (ten times) *better* than the process in bandwidth and frequency response. Dr. Campbell predicts that this information soon will be made available. Among the vital specifications will be (1) nominal horse-power rating, (2) nominal phase shift at various frequencies, and (3) frequency response.

Here is the clarion call to all instrument manufacturers. Waste no time. Provide these theoretical men with all the operational data at your disposal. The next step forward then will be theirs!

Community Action

THE Detroit Section of the ISA has started an activity that has great implications for good. In the February 1952 issue of the Detroit ISA "Recorder," J. D. McCullough of the Ethyl Corporation asks his fellow members if they wish to volunteer in an advisory or emergency consulting basis. The fields in which activity is contemplated are: (a) Radioactivity measurements, (b) electron microscopy, (c) optical microscopy, (d) biochemistry, (e) electronic amplifiers and servomechanisms, (f) polarography, (g) air conditioning, (h) spectroscopy, (i) electrophoresis, and (j) oscillography.

There are groups in each of the above fields that need help. And there is no single group of men who can provide better "know-how" than instrument men. For example, most cities have a cancer research group working on problems of the greatest importance to humanity. The members of the instrumentation fraternity can use their skills to benefit their fellow man in this direct manner. We urge all instrument men to consider and investigate activity of this type.

Next Month's Features

Standardization

Next month, Messrs. Klingenberg and Elliott of the Chemical Plants Division of the Blaw-Knox Construction Co. will show the advantages that a degree of standardization would bring to instrument manufacturers and users alike. More important, a program is suggested that would lead to the benefits of standardization with minimum pain. We urge careful thought on this important subject and look forward to some concrete action by the most dynamic group in America—the instrument men.

Servomechanisms

Also in next month's issue will be two articles on electromechanical servomechanisms. Mr. P. H. Williams of Servomechanisms, Inc., will describe the features of the devices, and Mr. R. G. Durnal, of Westinghouse Electric Corp. will show their application in control of processes by "indirect variables"—that is, by controlling secondary effects which are linear (but not straight-line) functions of the primary process variable.

Electrometer

The application of the vacuum-tube electrometer will be discussed next month by J. F. Keithley of Keithley Instruments, Inc. This familiar research instrument can have many industrial uses.

Stability

Mr. J. A. Baring of Askania Regulator Co., will present a clear and simple discussion of the two factors that determine controlled-plant stability—amplitude-frequency response and (2) phase change. He will examine the open-loop response to show the effect of plant and regulator.

Instrument Electronics

M. H. Aronson will conclude his discussion of electronic amplifiers with the subjects of video amplifiers, biasing methods, feedback, cathode followers, electrometer tubes, and noise level.

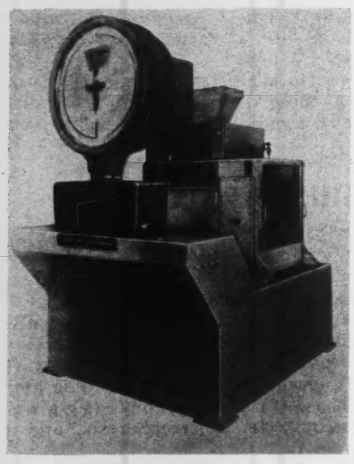
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, computing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 373

Automatic Proportioning System

New "Select-O-Weigh" system places automatic weighing within range of small plants; one automatic scale accomplishes work of twelve scales for

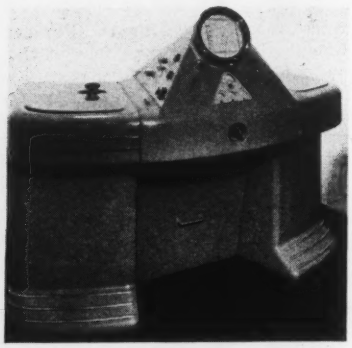


all proportioning operations. Electronic circuit is suited for explosion-proof installation. Standard scale is weighing element. Master control panel includes as many setting dials (up to 12) as there are ingredients in formulae handled. Operator, at any remote location, sets each dial for amount of each ingredient. Screw feeder mechanism then delivers to scale amount of material set on first control dial and then stops. Scale then either discharges to mixer or adds next ingredient to preset amount. Control circuits provide either (1) delivery of consecutive weights of varying amounts according to schedule, or (2) accumulation of a total batch of a formula and its discharge as a whole. Tare check circuit prevents next weighing until unit is in perfect empty balance.—*Richardson Scale Co., Clifton, N. J.*

Mention No. 301 when filling out card.

Electron Microscope

New "EM-100" electron microscope has resolving power of 30 A.u. and screen magnification continuous from 1000X to 60,000X. Accelerating potentials of 40, 60, 80, and 100 kv. are available. Large field permits recording of large areas. Roll-film 35-mm. camera permits 40 exposures at one loading and allows enlargements to 12X. Features: Positioning and film transport under vacuum; built-in photometer; immediate change-over for electron diffraction patterns; selected particle under con-

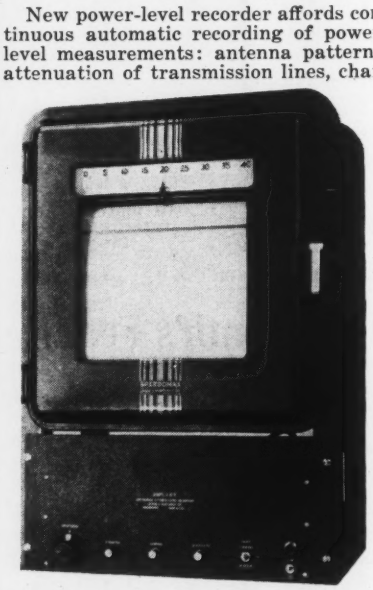


tinuous observation; clear images; low chromatic aberration; beam-alignment system operated by finger-tip controls. —*North American Philips Co., 750 S. Fulton Ave., Mount Vernon, N. Y.*

Mention No. 302 when filling out card.

Power-level Recorder

New power-level recorder affords continuous automatic recording of power-level measurements: antenna patterns, attenuation of transmission lines, char-



acteristics of filter networks, etc. Principle is attenuating input signal to match a constant internal reference voltage. Full-scale reading is 20, 30, 40, 50, or 60 db above reference level of 0.0002 milliwatt. Full-scale changes recorded in less than 2 seconds. Limit of error is 0.5 percent of full scale within 40 to 150,000 cps.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Penna.*

Mention No. 303 when filling out card.

Electron Microscope

New "Model EST 1" electrostatic electron microscope with resolving power of 30 A.u. has new electrostatic lens system that simplifies operation. Specimen image does not rotate with changes of magnification. Features in-

clude high image quality at direct magnifications up to 20,000X, large-area viewing screen, built-in camera without air lock, and high-intensity electron gun with replaceable filaments. Instrument is adaptable for electron diffraction and stereo electron micrographs.—*Farrand Optical Co., Inc., Bronx Blvd. & E. 238th St., New York 70, N. Y.*

Mention No. 304 when filling out card.

Spectrometer

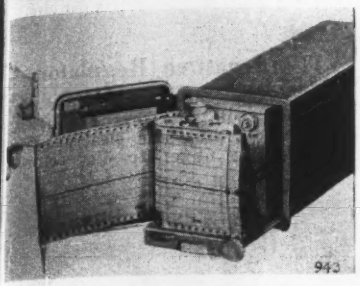
New "Model 112 Infrared Spectrometer" provides double-monochromator performance with single-monochromator simplicity. Features of "Model 12-C

Spectrometer" are retained, including simple-prism interchange, mobile mounting console, automatic wavelength speed scheduling, micro and macro sampling, and provision for polarization studies.—*The Perkin-Elmer Corp., Norwalk, Conn.*

Mention No. 305 when filling out card.

Miniature Recorder

New "Autronic Recorder" is independently-powered null-balance miniature strip-chart recorder for maker's "Autronic Control System." Unbalance between output of primary-element transmitter (0-0.5 v. a.c.) and balancing transformer is amplified to drive

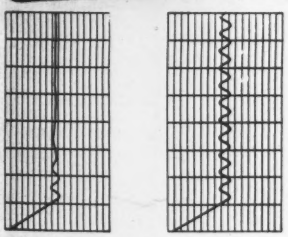


rotary-solenoid motor for positioning pen. Pen traverses 3-inch chart in 0.5 second; response-speed is adjustable. Plug-in connections permit entire recorder to be removed. Mechanism can be pulled 3 inches to inspect past records without stopping recorder. Three-hour record visible at all times. Standard chart speed is 1 inch per hour. A 30-day chart is supplied, with linear or square root graduations, or in terms of variable being measured. Available with or without built-in set-point adjustment.—*Swartwout Co.*, 18511 *Euclid Ave., Cleveland* 12, *Ohio.*

Mention No. 306 when filling out card.

Temperature Controller

New "Model J Gardsman" proportioning indicating pyrometric controller, in price range of off-on controllers, controls ratio of fuel or power "on" and



PROPORTIONING CONTROL

OFF ON CONTROL

"off" over time-cycle to maintain temperature. Controller anticipates and corrects for thermal inertia, preventing overshooting. Pointer indicates temperature at all times because proportioning action takes place in controller section only. "Model JP" is available

NEW DUO-SEAL VACUUM PUMPS
Foster Pumping — Longer Service

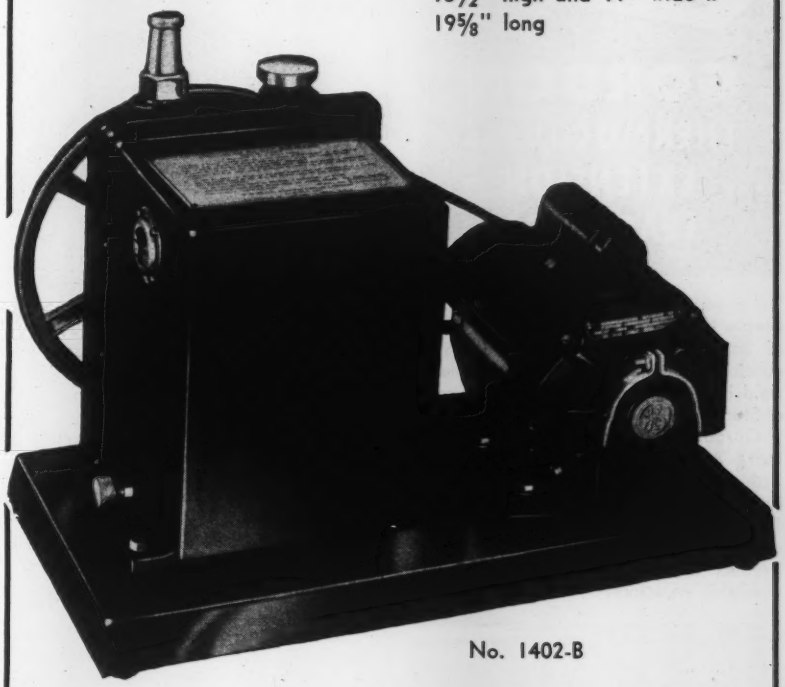
HIGH CAPACITY
5 cubic feet per minute
(140 liters per minute)

GUARANTEED VACUUM
0.0001 mm Hg or 0.1 microns

QUIET OPERATION

VISIBLE OIL LEVEL

COMPACT DESIGN
Overall dimension for pump and motor
15½" high and 11" wide x 19⅝" long



No. 1402-B

This new two-stage Duo-Seal pump is constructed with the same care and precision as its fore-runners in the Duo-Seal line. The extremely quiet operation, so much appreciated in the other models, is also characteristic of this unit.

A positive oil seal prevents the oil from backing into the exhaust line. Oil may be changed in a few minutes due to the conveniently located oil drain.

Available for Immediate Shipment.

1402. DUO-SEAL TWO-STAGE VACUUM PUMP. Pump unit only, not mounted on a base, but with a 10 inch grooved pulley, a supply of oil, and directions for use.
***Each* $190.00**

1402B. DUO-SEAL PUMP, MOTOR-DRIVEN. A No. 1402 Pump mounted on a base with a ½ H.P. 115-volt A.C. motor. Complete with pulleys, belt, and cord.
***Each* $250.00**

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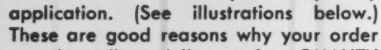
Manufacturers of Scientific Instruments and Laboratory Apparatus

The precision quality of Gordon Thermocouple Extension Lead Wire is the result of continued experience since 1915 in careful selection and inspection that meets rigid insulation requirements and Bureau of Standards specifications.

Gordon's Chicago and Cleveland plants carry complete stocks of Thermocouple Extension Lead Wire for practically every application. (See illustrations below.) These are good reasons why your order gets immediate delivery of a QUALITY product. ORDER NOW! No delays. Prices available on request.



CHROMEL-ALUMEL, Cat. No. 1231(3-A), 14 ga., STRANDED-DUPLEX, each wire felted asbestos, Asbestos-yarn braid overall.

FOR PLATINUM THERMOCOUPLES, Cat. No. 1225, 16 ga., STRANDED-DUPLEX, each wire felted asbestos, Asbestos-yarn braid overall.

CHROMEL-ALUMEL, Cat. No. 1234, 14 ga., SOLID-DUPLEX, each wire enamel, felted asbestos, Asbestos-yarn braid overall.

IRON-CONSTANTAN, Cat. No. 1236-C, 14 ga., STRANDED-DUPLEX, each wire felted asbestos, Asbestos-yarn braid overall.

COPPER-CONSTANTAN, Cat. No. 1235-A, 14 ga., SOLID-DUPLEX, each wire cotton, rubber, weatherproof braid, lead sheath overall.

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NEW INSTRUMENTS

in 36 standard scale and thermocouple ranges; power is 115 or 230 v. 60-cycle. —*Taco West Corp., 525 N. Noble St., Chicago, Ill.*

Mention No. 307 when filling out card.

Absolute-pressure Indicator

New absolute-pressure indicator requires no corrections for barometric pressure changes, temperature, or altitude; is calibrated from 0 to 4, 8, or 16

in. mercury. Scale length of 6-in. dial is 16 in., giving a scale magnification of 4 to 1 compared to a mercury column. Ranges as low as 0-1 in. mercury are available. Instrument can be calibrated to read inches of mercury vacuum at standard conditions.—*Wallace & Tiernan Products, Inc., Belleville 9, N. J.*

Mention No. 308 when filling out card.

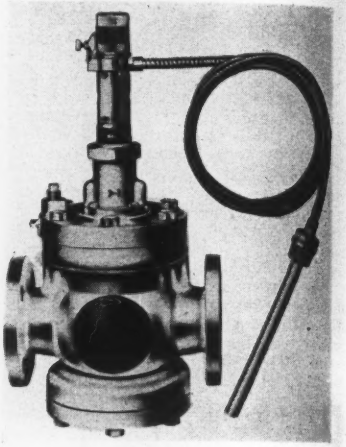
Humidity Controller

New "H 64A" humidity controller, considerably less expensive than maker's electronic model, utilizes a hair hygroscopic element. Under most conditions, operating differential is less than five percent.—*Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.*

Mention No. 309 when filling out card.

Temperature Regulator

New "Type 1005" self-operated temperature regulator is easily disassembled for relapping and cleaning. Features: visual finger-tip dial control;

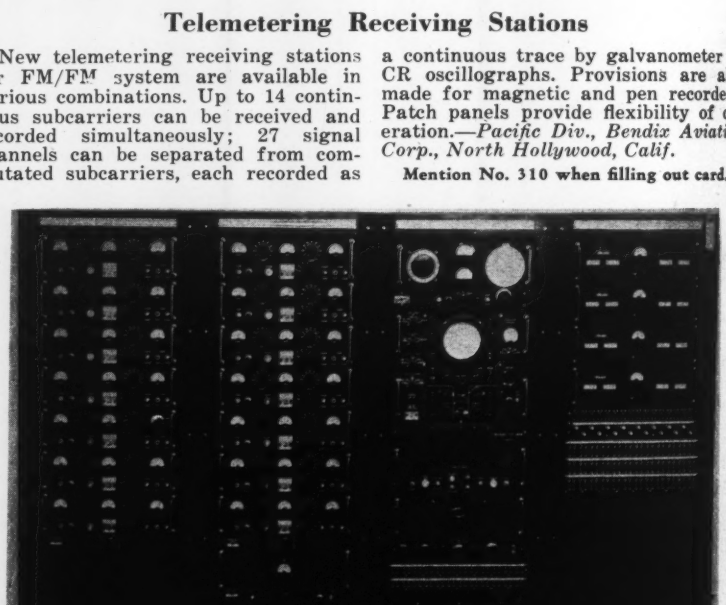


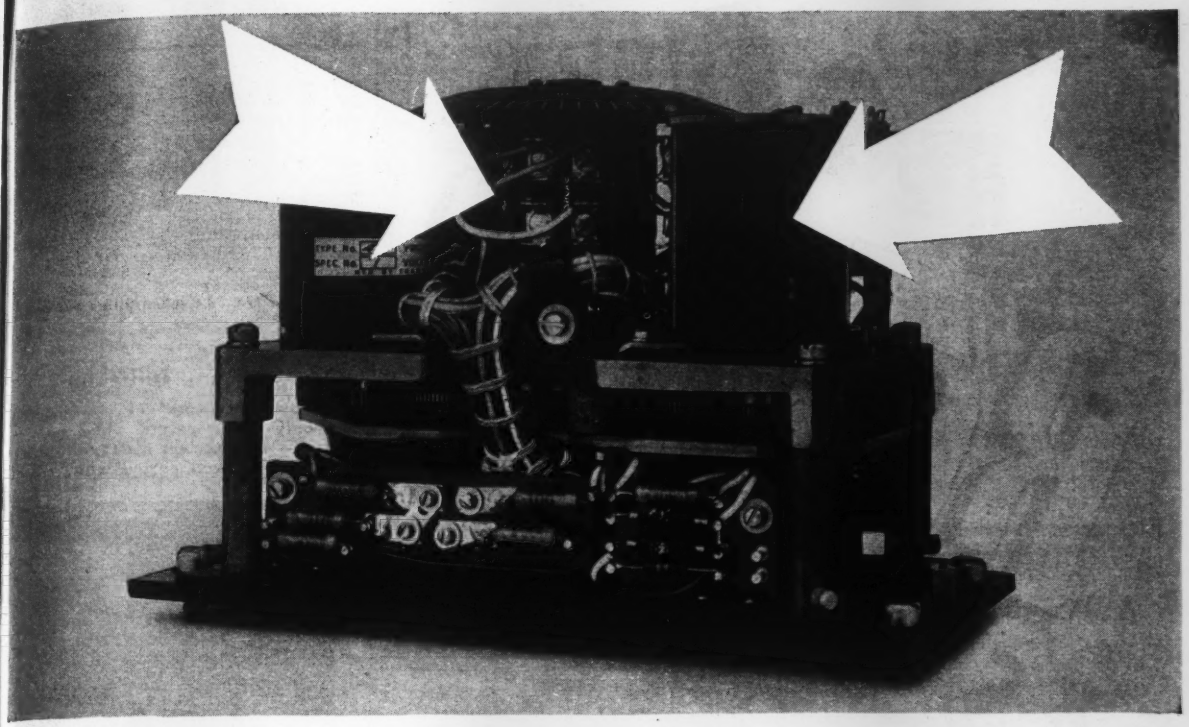
built-in strainers; stainless-steel seats and disks; and internal porting. Control accuracy is 1 deg. F., obtained by

Telemetering Receiving Stations

New telemetering receiving stations for FM/FM system are available in various combinations. Up to 14 continuous subcarriers can be received and recorded simultaneously; 27 signal channels can be separated from commutated subcarriers, each recorded as a continuous trace by galvanometer or CR oscillographs. Provisions are also made for magnetic and pen recorders. Patch panels provide flexibility of operation.—*Pacific Div., Bendix Aviation Corp., North Hollywood, Calif.*

Mention No. 310 when filling out card.





Potentiometer precision—where it counts!

Engineers at Servomechanisms, Inc., needed control components that would go hand-in-hand with the extremely high accuracy they designed into this computer for a radar-gunfire control system. Two 3-gang Fairchild precision potentiometers are used for two principal reasons—

1. they have extremely high functional accuracy, and
2. their precision mechanical design eliminates backlash and binding which would cause serious errors in the computing system.

These potentiometers are driven through 72-pitch stainless-steel gears. Fairchild potentiometers depend on more than just accurate windings for precision. For details see below.

HOW PRECISION IS BUILT INTO FAIRCHILD POTENTIOMETERS

1. The *shaft* is centerless-ground from stainless steel to a tolerance of +0.0000, −0.0002 in. which together with precision-bored bearings results in radial shaft play of less than 0.0009 in.

2. The *mounting plate* has all critical surfaces accurately machined at one setting to insure shaft-to-mounting squareness of 0.001 in/in. and concentricity of shaft to pilot bushing within 0.001 in. FIR.

3. The *housing* is precision-machined from aluminum bar stock. Close tolerance of this construction permits ganging up to 20 units on a single shaft without eccentricity of the center cup, even though only two bearings are used for the entire gang.

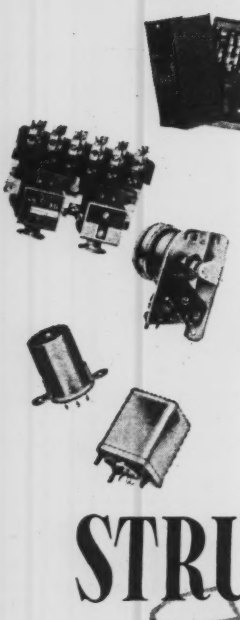
4. The *windings* are custom-made by an exclusive technique. Guaranteed accuracy of linear windings in the types illustrated is 0.5%; non-linear 1.0%. Higher accuracies (to 0.05%) are available in other types. Guaranteed service life is 1,000,000 cycles.

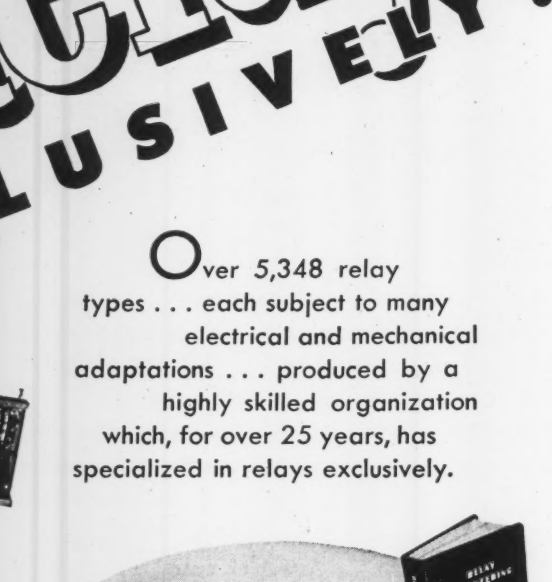
DO YOU NEED THIS KIND OF PRECISION? *Fairchild Sample Laboratory engineers are available to help on special potentiometer problems. To get the benefit of their knowledge and experience write today, giving complete details, to* Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, New York, Department 140-24B.

FAIRCHILD
PRECISION POTENTIOMETERS

Relays EXCLUSIVELY!

Over 5,348 relay types . . . each subject to many electrical and mechanical adaptations . . . produced by a highly skilled organization which, for over 25 years, has specialized in relays exclusively.





Here is relay experience!

"RELAY ENGINEERING" the famous 640-page handbook brings you full benefit of Struthers-Dunn's experience in producing thousands of relay types for hundreds of applications. A complete, fully-illustrated guide to all phases of relay selection, use, circuitry and maintenance. Price $3.00.

STRUTHERS-DUNN

5,348 RELAY TYPES

Struthers-Dunn, Inc., 150 N. 13th St., Philadelphia 7, Pa.

BALTIMORE • BOSTON • BUFFALO • CHARLOTTE • CHICAGO • CINCINNATI
CLEVELAND • DALLAS • DETROIT • KANSAS CITY • LOS ANGELES
MINNEAPOLIS • MONTREAL • NEW ORLEANS • NEW YORK • PITTSBURGH
ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO

vapor-flash pilot-operating principle: 99 percent of power to position valve is taken directly from steam, 1 percent from vapor expansion in thermostatic system. Sizes 2-in. through 4-in.; with 125-lb. or 250-lb. ASA flanges for steam pressures from 10 to 150 psig. and for temperature control from 30 to 325 F. (adjustment range 60 F.)—*Farris Stacon Corp., 610 Commercial Ave., Palisades Park, N. J.*

Mention No. 311 when filling out card.

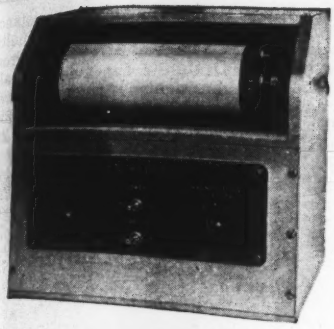
Oxygen Indicator

New "Type C-2" oxygen indicator has only three points which need attention—(1) carbon electrode, which must be replaced periodically; (2) detector cell, which requires an ounce or two of oxylite every two weeks; and (3) one No. 2 flashlight cell, which must be replaced every week. Standard full-scale ranges are 0 to 1, 5, 10, and 25 percent. Scale with 50 graduations yields oxygen concentrations to two percent.—*Mine Safety Appliances Co., Braddock, Thomas, and Meade Sts., Pittsburgh 8, Penna.*

Mention No. 312 when filling out card.

Drum-chart Recorder

New "Model 51 Electronic Recorder" for use with universal testing machines has automatic null-balance system which rotates chart drum in direct proportion to strain or deformation of specimen under test, while testing machine produces a stress coordinate by horizontal movement of non-clog pen. Sensitivity is 0.05 percent of full scale for each range; accuracy of strain coordinate is 1/5 division (0.2 percent of full scale); accuracy of stress coordinate equals that of testing machine. Magnifications from 1000:1 to 1:1 are available by switch. Can be applied to all testing machines. When used with beam and hydraulic gage types, an additional

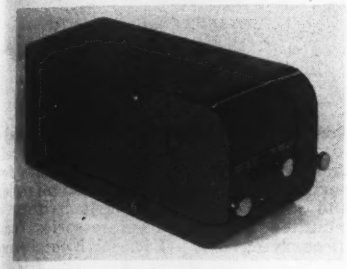


null system is necessary to drive load pen across chart.—*Tinius Olsen Testing Machine Co.*, 1116 *Easton Rd., Willow Grove, Pa.*

Mention No. 313 when filling out card.

Multi-channel Oscillograph

New "Model 555" oscillograph has small size, accuracy, and ruggedness. Among features: 14 channels, trace identification (beam interrupter type),



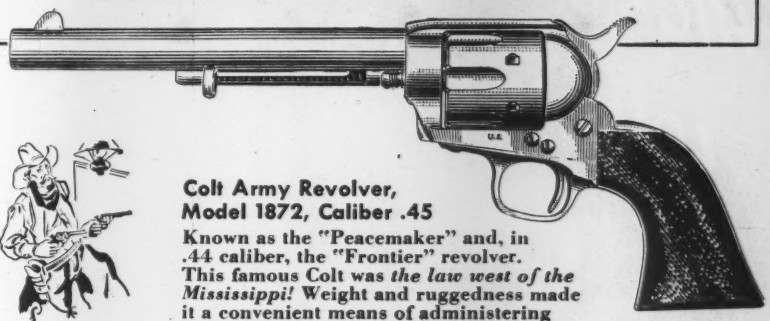
electronic timing lines at 0.01 or 0.1 sec. intervals, and continuously variable paper speed from ½ to 12 inches per second. Galvanometers available with undamped natural frequencies from 100 to 3500 cps. Oscillograph weighs 12 lbs., operates on 24 volts d.c., and uses 3⅝-inch paper.—*Midwestern Geophysical Laboratory*, 2803 *West 40th St., Tulsa, Okla.*

Mention No. 314 when filling out card.

Megohmmeter

New "Type 1862-A Megohmmeter" requires only turning of a multiplier switch; resistance is read directly. Range is from 0.5 megohm to 2,000,000 megohms, in six decades. Test voltage

Famous Guns



Colt Army Revolver, Model 1872, Caliber .45

Known as the "Peacemaker" and, in .44 caliber, the "Frontier" revolver. This famous Colt was *the law west of the Mississippi!* Weight and ruggedness made it a convenient means of administering a "pistol whipping".

Model 1808 Navy Pistol, Caliber .64, made by Simeon North of Berlin, Conn. Boarding pistols like this rendered valuable service in the War of 1812. In building them, North actually used a modern mass production technique—*standardized parts!*

Instant-heating

Weller Soldering Gun for light or heavy work. Dual heat greatly increases tip life. Switch instantly to high or low heat as job requires. Pre-focused spotlights end "blind soldering". Exclusive tip-fastening arrangement assures full, constant heat. High-impact plastic housing. Perfect balance. Low-cost replaceable tips. Pays for itself in a few months. See at your Distributor or write for Bulletin direct.

Get SOLDERING TIPS, new Weller Handy Guide to faster, easier soldering. 20 pages fully illustrated. Price 10c at your Distributor or order direct.

Weller BETTER FROM GRIP TO TIP

SOLDERING GUNS 800 Packer Street, Easton, Pa.

The Finest Soldering Tool for the Finest Craftsmen

In This
NEW Bendix-Pacific
TELEMETERING COMMUTATING SWITCH

Commutation of telemetering subcarrier oscillator input voltages or pickup output at high sampling rates can now be provided with this new Bendix-Pacific TSC-18 Commutating Switch.

The TSC-18 Commutating Switch is a three pole switch having 60 contacts per section and shorting type contact wipers. Non-shorting type operation may be obtained by connecting to alternate contacts giving 30 circuits in each section with 60% duty cycle. The wipers are adjustable for synchronization of all sections.

Long life has been engineered into the switch through the use of heat treated precious metal contact pins and wipers. The contact plate and rotor are completely enclosed in an aluminum housing which is attached to a small permanent magnet motor having an integral gear train and governor.

SPECIFICATIONS

Motor Voltages: 6, 12, or 28 volts DC.
Motor Current: 300 to 500 ma.
Capacities: Adjacent pins: 2.8 mmfd.
Alternate pins: 2.2 mmfd.
Inner to middle slip ring: 19.2 mmfd.
Outer to middle slip ring: 18.3 mmfd.
Outer to inner slip ring: 16.7 mmfd.
Temperature range: −50°C to +100°C
Acceleration: Satisfactory to 40 G along any axis
Vibration: Satisfactory to 20 G at a frequency of 55 cps or 10 G to 600 cps along any axis
Dimensions: 3.5" max. diameter; 4.98" max. length
Weight: 1.18 pounds

Write for complete information

Bendix
Pacific Division
Bendix Aviation Corporation
NORTH HOLLYWOOD CALIF.

TO MEASURE..TO WARN..TO INDICATE..AT A DISTANCE

of 500 volts is applied to resistance under test; discharge position of multiplier switch removes all voltage from terminals. Designed for field and laboratory, instrument is rugged. Power is a-c. line.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 315 when filling out card.

Combustion Analyzer

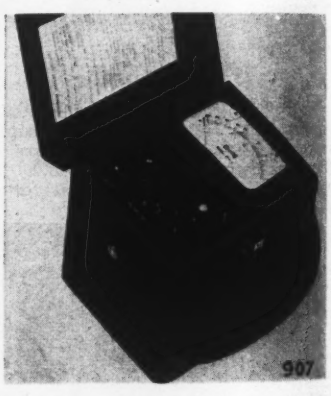
New "Model 140 Veco Combustion Analyzer" indicates (1) CO_2 content of flue gas, (2) flue-gas temperature, and (3) over-fire draft on one dial. Feature is single sampling tube with built-in

thermocouple, making instrument easy to operate. Analyzing element and reference element are sealed in glass for permanent protection against corrosion and shorting. Small 6-volt battery is mounted in cabinet; accessories come in carrying bag.—*Victory Engineering Corp., 744 Broad St., Newark, N. J.*

Mention No. 316 when filling out card.

Precision Ohmmeters

New Models "244A" and "264A" ohmmeters have compensation for aging of internal resistance of batteries and for lead resistance. Accuracy is



1/32 inch at any point on scale and 0.5 percent at mid-scale. "Model 244A" has ranges of 0-50, 500, 5,000, and 50,000 ohms. "246A" has ranges of 0-100, 1000, 10,000, and 100,000 ohms. Weight is 11.25 lbs.—*Associated Research, Inc., 3758 W. Belmont Ave., Chicago 18, Ill.*

Mention No. 317 when filling out card.

Octave-band Noise Analyzer

New "Type 1550-A Octave-band Noise Analyzer" has eight pass bands. Lowest is low-pass filter; highest is high-pass filter; middle six, covering from 75-4800

cycles, are each one octave in width. Amplifier, calibrated attenuator, and indicating meter measure octave-band levels over range of 60 db. Operates from output of standard sound-level meter.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 318 when filling out card.

Electrometer Shunt

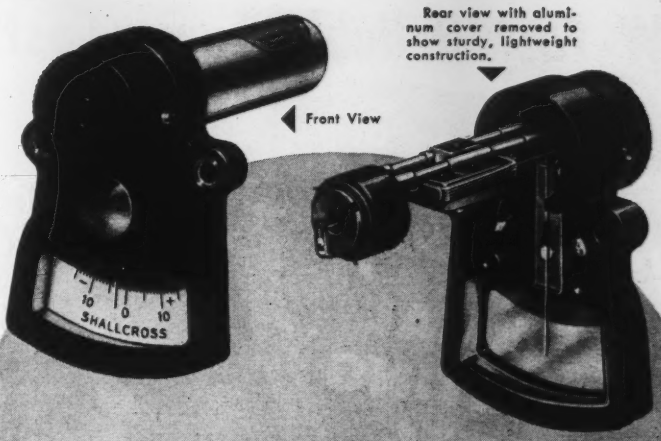
New "Model 2001" electrometer shunt permits quick conversion of maker's "Model 200" electrometer to a micro-microammeter; is available in seven

standard resistance values; permits direct-current readings from 10^{-6} to 10^{-13} ampere.—*Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio.*

Mention No. 319 when filling out card.

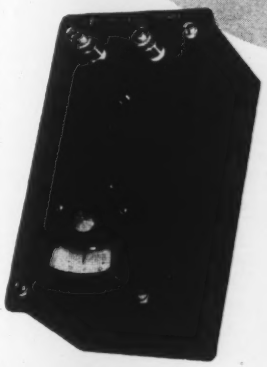
Pulse Generator

New "FX-100" portable X-ray pulse generator consists of: (1) control unit containing high-voltage RF power supply and high-voltage pulse circuit, and

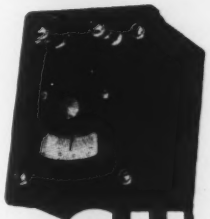


A New Improved Galvanometer Movement...at Modest Cost

Use of the proven taut-suspension principle assures light weight, minimum size, and low cost for these new Shallcross Type 1951 galvanometer movements. To minimize weight and simplify construction the coil system is suspended on sturdy rod supports instead of a heavy phenolic base. Mounting dimensions are standard and the units are supplied in sensitivities of 0.5—1.—2. and 4 microamperes per mm. scale division.



SERIES 316



SERIES 315

...and Two New Galvanometers

Only 4⅞" x 4⅜" x 3⅜", the new Shallcross Series 315 galvanometer is ideally suited for field, laboratory or production use where low cost and portability are important factors. Where large current variations are encountered, the Shallcross 316 Series with built-in Ayrton shunt switch provides greater versatility. Both types utilize the new Shallcross Type 1951 galvanometer movement. Write for bulletin *L-26* to: SHALLCROSS MANUFACTURING COMPANY, Collingdale, Pa.

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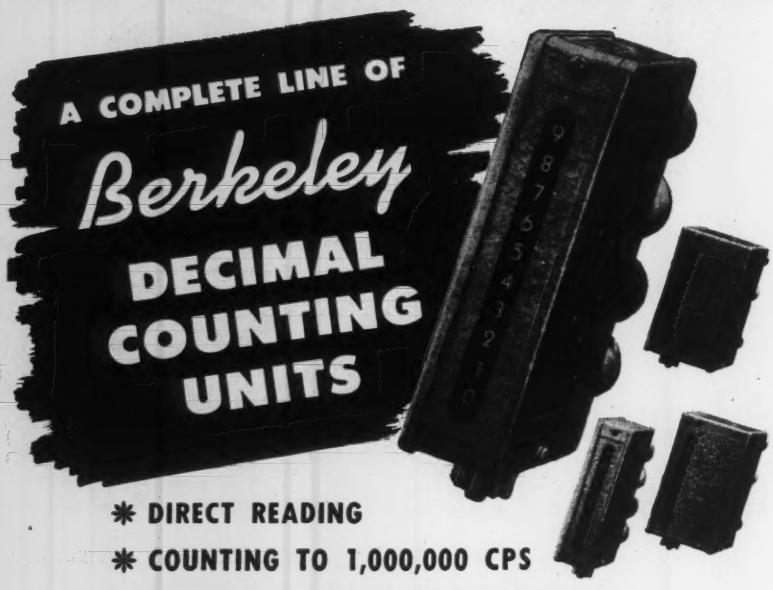

* DIRECT READING
* COUNTING TO 1,000,000 CPS
* RUGGED PLUG-IN CONSTRUCTION

Berkeley's complete line of decimal counting units includes the improved Models 700A and 705A, now offering higher counting speeds, increased stability and longer operating life. Two new units, the 706A and 707A, have been added to provide maximum counting rates of 350,000 and 1,000,000 cps respectively. All units are designed for cascade arrangement to provide any desired total count capacity. All units of same model number interchangeable without adjustment. Instantaneous reset to zero through opening of grid return circuit.

SPECIFICATIONS

	MODEL 700A	MODEL 705A	MODEL 706A	MODEL 707A
Maximum Counting Rate	40,000 cps	100,000 cps	350,000 cps	1,000,000 cps
Resolution—Pulse Pairs	5 μ sec.	5 μ sec.	1 μ sec.	0.8 μ sec.
Tubes	4-5963	4-5963	4-5963 5-6AL5	4-5687 6-6AL5
Plug-In Mounting	Octal	Octal	11 pin	11 pin
Dimensions	1⅜"x5½"x5½"	1⅜"x5½"x5½"	2½"x5½"x5½"	3¼"x5½"x5½"
Weight	12 oz.	12 oz.	24 oz.	24 oz.
Price*	$50	$60	$95	$145

* **LOWER COST—*A Berkeley Policy***

Continually-widening applications for Berkeley instruments and components have enabled us to realize substantial economies in manufacturing cost. These benefits are distributed equably among those who have made them possible—our customers, our engineering and manufacturing group, and our field organization. To you, the user of Berkeley instruments, these benefits accrue in the form of better and better equipment at lower and lower cost.

FOR COMPLETE INFORMATION, please write for bulletin 700 I.

Berkeley Scientific Corporation

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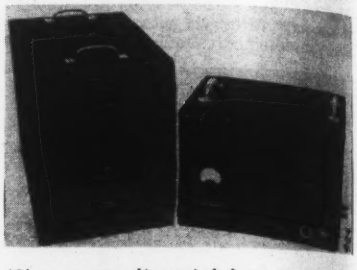


(2) power unit containing pulse transformer and capacitor. X-ray tube is attached to front of power unit. Equipment is designed for radiographic recording of ultra-speed phenomena, as in ordnance and ballistics; also industrial research, particularly dynamic stress analysis.—*Microtime Laboratories, 2231 S. Barry Ave., Los Angeles 64, Calif.*

Mention No. 320 when filling out card.

Electric Tachometers

New electric tachometers have guaranteed accuracy of 0.25 percent of any speed being measured. Simple calibration adjustments are on front of instru-

ments. Ten overlapping ranges provide 10-to-1 spread in speed. Three scales provide good readability of minor divisions.—*Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.*

Mention No. 321 when filling out card.

Amplifying Stethoscope

New "Lectron-O-Scope" provides up to 50X amplification; weighs 9 oz.;

contains both microphone and speaker; attaches on doctor's regular binaurals. —*Electronic Stethoscope Corp.*, 1316 *Sherman Ave., Evanston, Ill.*

Mention No. 322 when filling out card.

Under-frequency and Overspeed Controls

Two new automatic devices are for 400-cps. aircraft electrical systems and portable engine-driven generating sets: (1) New "Under-frequency Control"

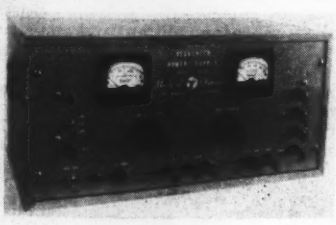
trips circuit breaker if frequency drops below 360 and closes circuit breaker when frequency is restored to 400 cps. Uses no electronic components; weighs 16 oz.; can be adjusted to 2-cps. differential.

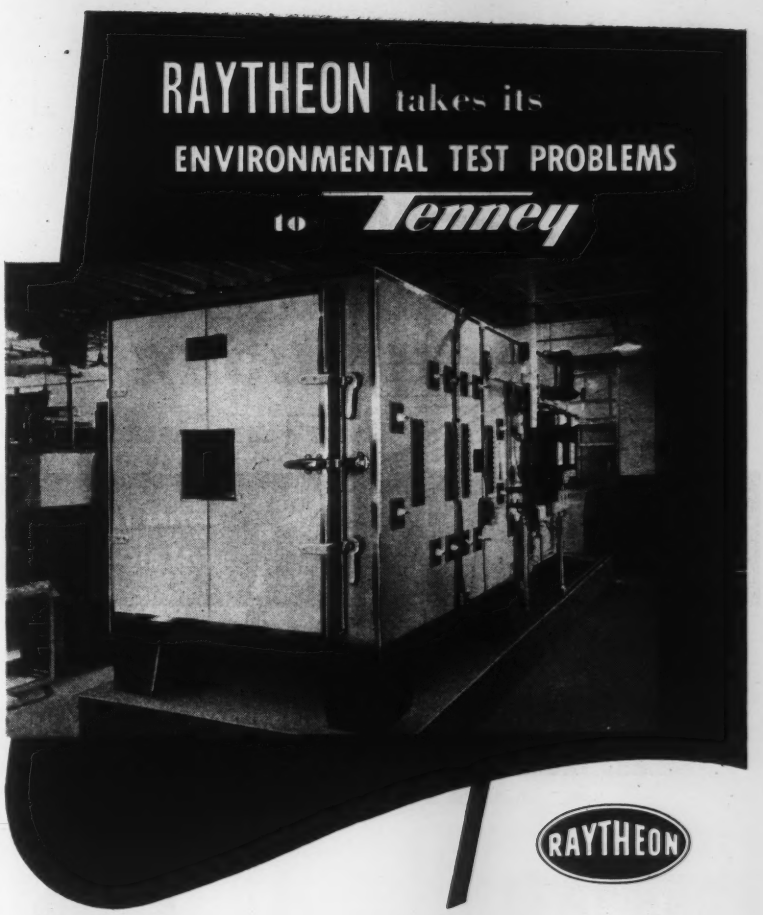
(2) New "Overspeed Safety Control" for engines and turbos takes speed reference either from ignition system of engine or tachometer generator of turbo; shuts off fuel and/or ignition, should overspeed occur; does not require lubrication or field adjustments.—*Electroquipt Controls, Inc.*, 30 *Sagamore Hill Drive, Port Washington, N. Y.*

Mention No. 323 when filling out card.

Regulated Power Supply

New "Model 100A-5" regulated power supply furnishes 0 to 500 v. d.c. at 0 to 300 ma.; bias voltage from 0 to -150 v. at 2 ma. Also two outputs of low a.c. either 6.3 v. at 6 amp. or 12.6 v. at 3 amp. Regulation is better than 0.2-volt





A tank in battle takes far less punishment than the delicate electronic components in modern military equipment. To ensure the operational durability of products bearing the trademark "Raytheon," this leading manufacturer of precision electronic equipment and tubes of Waltham, Mass., employs this Tenney Test Chamber in a complete environmental test program.

Specifications: temperature range, −85°F to +200°F; pull-down to −70°F with 1000 lb. mass load within 1 hr.; dissipation 2 kw at −70°F; relative humidity, 20% to 95%; altitude to 75,000 ft. Maximum flexibility and ease in setting up tests are ensured by a bank of 144 terminal connectors and 12 high-voltage lead-ins.

For all types of testing—development, research, specification, and production—a Tenney-engineered chamber will meet your requirements. For testing under all degrees of humidity, at all altitudes and temperatures, a Tenney-built test chamber assures complete dependability and precisely controlled test data. Automatic cycling, indicating, and/or recording systems to your specifications, if desired.

For further information without obligation, write Tenney Engineering, Inc., Dept. D, 26 Avenue B, Newark 5, New Jersey.

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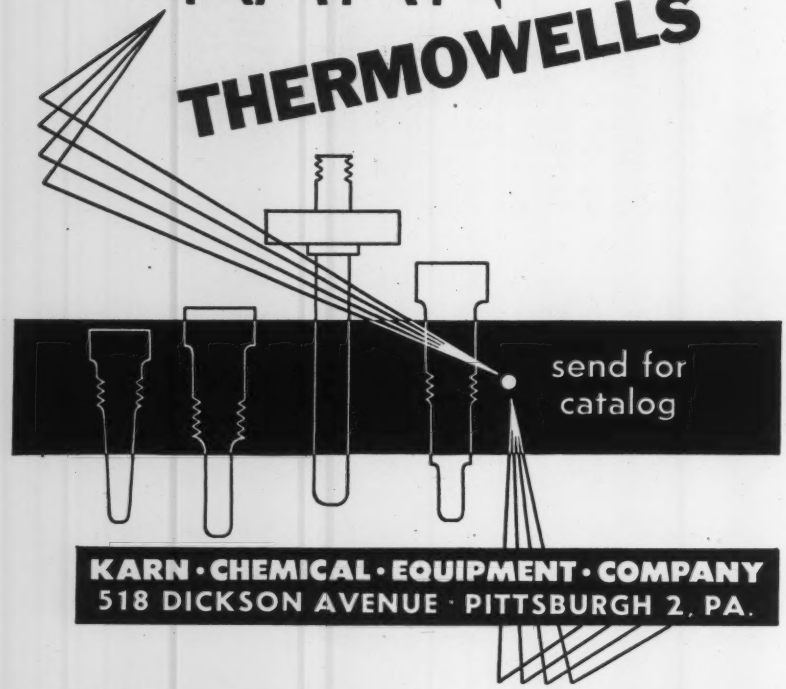

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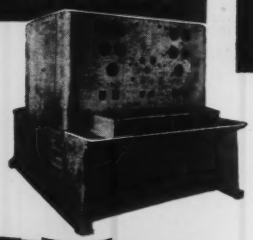

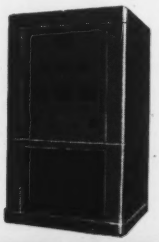

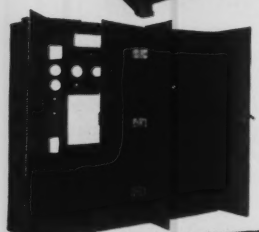

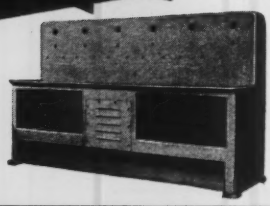

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variation from no load to full load, 0 to 500 volts, or for line fluctuations from 105 to 125 volts. Hum is 2 mv. r.m.s.—*Universal Electronics Co., 2012 S. Sepulveda Blvd., Los Angeles 25, Calif.*

Mention No. 324 when filling out card.

Regulated Power Supply

New "Kepco Model 3100" low-voltage regulated power supply has d-c. output voltage variable from 0-3 volts at 0-100 ma. Output voltage variation is less

than 5 millivolts for line fluctuations from 105-125 volts and load variation from 0-100 ma. Ripple is less than 1 millivolt. Dimensions are 19 x 7 x 11 in.—*Kepco Laboratories, Inc., 131 Sanford Ave., Flushing 55, N. Y.*

Mention No. 325 when filling out card.

Voltage Tester

New "Wigginton Voltage Tester" is easy and safe to use. When not in use, prods can be inserted in bottom of receptacle, shielding sharp points. By

mounting one prod in either receptacle, direct probing can be made with both hands with voltage scale visible. By mounting both prods in top of receptacles, overhead testing is possible with scale at eye level.—*Square D Co., 6060 Rivard St., Detroit 11, Mich.*

Mention No. 326 when filling out card.

Sonic Oscillator

New magnetostriction oscillator consists of electronic driving element, hollow vibrator column, and cup assembly. Two sizes offered: small unit, operating at 9,000 cycles, has capacity of 25 c.c. and delivers 50 watts to magnetostriction rod. Larger unit has a capacity of 50 cc. and delivers 200 watts at 10,000 cycles.—*Dept. 6470 NR, Raytheon Mfg. Co., Waltham 54, Mass.*

Mention No. 327 when filling out card.

Output Meter

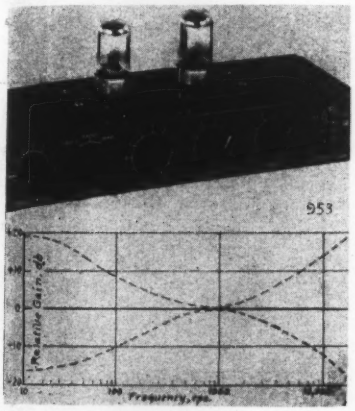
New "Type OP-961" 50-watt output power meter reads power or impedance accurately over a-f. range. Impedance is adjustable in 40 steps from 2.5 ohms

to 20,000 ohms. Instrument measures in steps of 0.1 milliwatt; is also calibrated from minus 10 to plus 47 db. Accuracy is 2 percent. Impedance-changing network remains resistive at audio frequencies; multiplier network has constant impedance at all frequencies.—*Daven Co.*, 191 *Central Ave., Newark, N. J.*

Mention No. 328 when filling out card.

Preamplifier

New "Model A-800" four-stage preamplifier for high-quality audio systems consists of (1) two-stage compensated amplifier for magnetic-type cartridge



and (2) two-stage tone-compensating non-resonant control circuit. Uses two 7F7 twin triodes. Upper and lower limits of bass and treble compensation are shown.—*Approved Electronic Instrument Corp.*, 142 *Liberty St., New York 6, N. Y.*

Mention No. 329 when filling out card.

Recording Counter-Chronograph

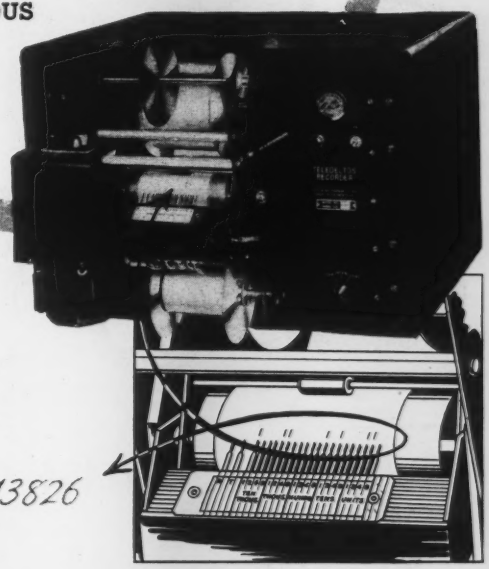
New "Recording Counter-Chronograph" has bank of stylii to record a rapid series of measurements such as individual velocities in a machine-gun burst. Data in digital form are transferred to electrically sensitive paper.

NOW...9000 records per minute!

with the **NEW POTTER** *high speed*

TELEDELTOS RECORDER

IMMEDIATELY VISIBLE
INSTANTANEOUS
PERMANENT
DIGITAL

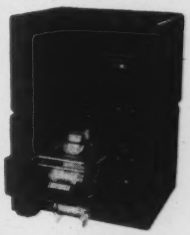


Designed to record measurements obtained on Potter Electronic counters, scalers, chronographs and frequency-time counters.

The Potter Instrument Co. High Speed Teledeltos Recorder provides a permanent recording of digital information at rates up to 150 six-digit answers per second. The measurements are transferred to electrically sensitive paper using four stylii for each digit arranged in the famous Potter (1-2-4-8) read-out. The records are indexed intermittently and controlled by the events being measured.

Write for information on specific applications to Dept. 4A.

POTTER RECORDING COUNTER CHRONOGRAPH



Measures time intervals up to 0.10000 second in increments of 2.5 microseconds. (Higher resolutions are also available.) Applicable to projectile velocity measurements, frequency measurements, geophysical measurements, telemetering and wherever micro-second timing is required.

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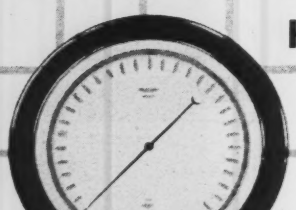

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Heise Gauges are used in many industries for precise measurements of pressure. Custom-built in pressure ranges from 0-15 to 0-10,000 psi. Sizes: 8½", 12", and 16" diameter. Standard gauges from $151.60 to $211.20. Gauges for use with mercury are $20.00 extra. Write for catalog.

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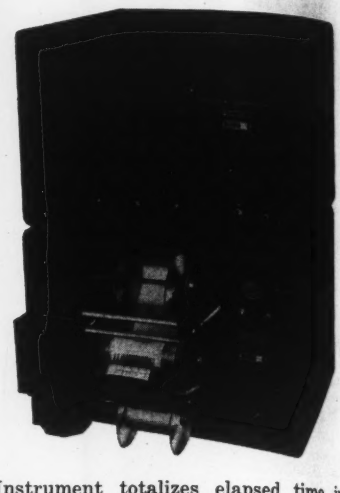


Instrument totalizes elapsed time in steps of ten microseconds or less. As many as 150 measurements per second can be recorded with a capacity of six digits for each. Paper roll is driven at any rate from 2.5 to 20 in./sec.—*Potter Instrument Co., Inc.,* 115 *Cutter Mill Road, Great Neck, N. Y.*

Mention No. 330 when filling out card.

Disk Recorder

New "Wagner-16 MicroDisc Recorder, Model P16-450," uses one-hour 16-rpm. unbreakable Vinylite disks with dia. of 4.75 in. and 448 lines per inch. Disk

drive uses no turntable, eliminates all flutter and wow. "Magic-eye" volume-level indicator is part of equipment. Weight is 28 lbs. with accessories.—*Audio & Video Products Corp.,* 730 *Fifth Ave., New York* 19, *N. Y.*

Mention No. 331 when filling out card.

Tape Reader

New "High Speed Tape Recorder Mk. 1" can read 5-digit teleprinter tape at speed of 250 characters per second. It emits a signal as soon as information from character is available; tape may then be stopped. If tape is stationary on

a character, next character is available for reading 5 milliseconds after "start" signal. Cathode followers transmit output from photocells. Output voltage swing between "hole" and "no hole" is 12 volts. Light source is standard 36-watt bulb. Entire photosensitive area of photocell is used.—*Ferranti Electric, Inc., 30 Rockefeller Plaza, New York 20, N. Y.*

Mention No. 332 when filling out card.

Volt-ammeter

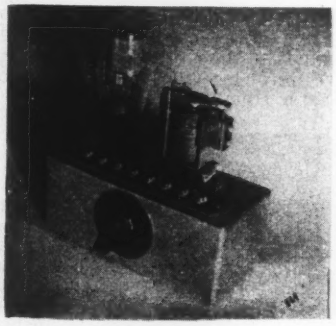
New "Model 1200 Amprobe" volt-ammeter measures up to 1200 amperes, is of "snap-around" type whereby reading can be taken without interrupting

circuit. Newly-developed doughnut-type transformer minimizes error due to position of conductor within probe jaws. Ranges: 0-15/60/150/300/600/1200 amperes a.c., and 0-150/300/600 volts a.c. Voltage test leads are equipped with new "Amprobe" safety plug which automatically insulates itself when removed from instrument.—*Pyramid Instrument Corp., Lynbrook, N. Y.*

Mention No. 333 when filling out card.

Electronic Timer

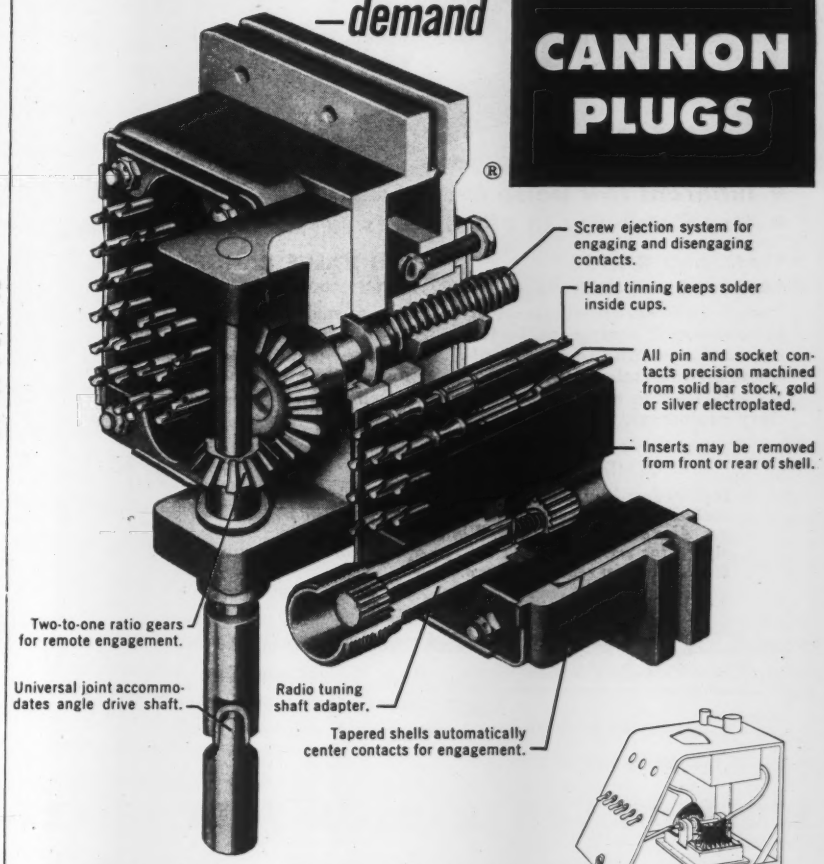
New "Model 701" electronic timer is accurate to 0.5 percent of time cycle. Time interval is adjustable from 0.05



Here's why those in the know

—demand

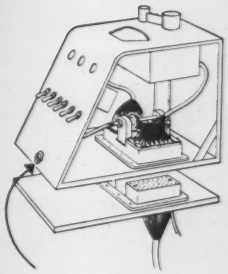
CANNON PLUGS ®


Screw ejection system for engaging and disengaging contacts.
Hand tinning keeps solder inside cups.
All pin and socket contacts precision machined from solid bar stock, gold or silver electroplated.
Inserts may be removed from front or rear of shell.
Two-to-one ratio gears for remote engagement.
Universal joint accommodates angle drive shaft.
Radio tuning shaft adapter.
Tapered shells automatically center contacts for engagement.

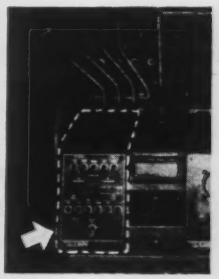
This highly specialized DPD2 Cannon Plug, a member of the DP Series, has its principal use in aircraft instrument panels and remote radio control equipment. But, like many other Cannon Plugs, it has found its way into other fields where the highest quality is needed and where the value of long, trouble-free performance is recognized.

Originally this 2-gang connector was designed to assist in the standardization of radio and instrument assemblies so that such equipment might be interchanged between similar aircraft. It allows for compact design in close quarters with access from the front only. This type of application and variations of the fittings are shown at right. Any Cannon DPD insert may be placed within the shell, with or without tuning shaft, coax, twinax, large or small contacts, provided the separation forces of both halves are similar.

This plug typifies the close attention to important detail that distinguishes every Cannon Plug—the world's most extensive line. If you are looking for real value, regardless of the field you work in, your best bet is Cannon.



Connector is separated by turning slotted shaft here. Complete unit may then be removed from pedestal, shown below.



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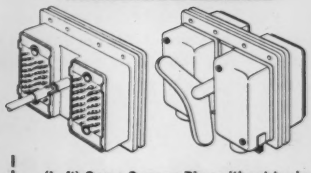
LOS ANGELES 31, CALIFORNIA

Factories in Los Angeles, Toronto, New Haven. Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. C-180, P.O. Box 75, Lincoln Heights Station, Los Angeles 31, California.



(Left) Same Cannon Plug without tuning shaft. Straight drive instead of 90° gear. (Right) Similar DPD2 with Dzus wing nut extraction method and junction shells. There are several other variations. Write for details.

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The All-Weather Resistors

TYPE 65X (Actual Size)

The resistors that give you...

- *Inherent low noise level*
- *Good stability in all climates*

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1,000 OHMS TO 9 MEGOHMS

These resistors are used extensively in commercial equipment, including radio, telephone, telegraph, sound pictures, television, etc. They are also used in a variety of U. S. Navy equipment.

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10 TO 10,000,000 MEGOHMS

This unusual range of high value resistors has been developed to meet the needs of scientific and industrial control, measuring and laboratory devices — and of high voltage applications.

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It gives details of Standard and High Value Resistors, including construction, characteristics, dimensions, etc. Also described are S. S. White 80X Resistors, designed for extremely high voltage equipment. Copy with Price List sent on request.

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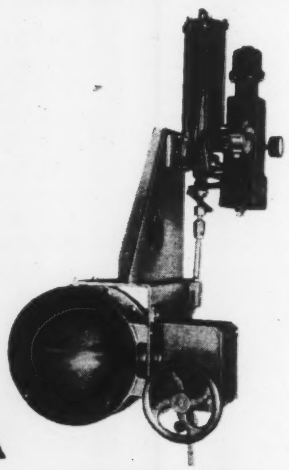
of air, gases, liquids and semi-solids at temperatures below freezing or as high as 1600°F, at pressures to 100 p.s.i.g. without clogging or breakdown? You can be sure — if you install Rockwell Butterfly Valves. Pipe sizes — 1" to 4" threaded; 4" to 72" flanged or wafer type.



Rubber-lined steel, heavy duty valve for 90 p.s.i. — with air cylinder operator, clutch and auxiliary handwheel control.

Write for Catalog and the monthly "Valve News"

ROCKWELL VALVES

W. S. ROCKWELL CO. • 264 Eliot St., Fairfield, Conn.

NEW INSTRUMENTS

to 20 sec. Cycle is initiated by contact closure. SPDT relay is operated at end of interval. Relay contacts are rated at 115 v. 5 amp.—*Timetrol Co., P.O. Box 193, Rockford, Ill.*

Mention No. 334 when filling out card.

Target-angle Recorder

New research instrument exposes 10 frames per sec. for two minutes to study aircraft flight-path and diving-angle variations. Camera is aimed at

aircraft by gunsight. By use of cross-hairs, operator moves film-drive mechanism and shutter assembly over graticule whose rulings and index numbers appear on finished pictures, which are analyzed to provide data. Recorder has provisions for t-v camera behind gunsight.—*Beckman & Whitley, Inc., 930 San Carlos Ave., San Carlos, Calif.*

Mention No. 335 when filling out card.

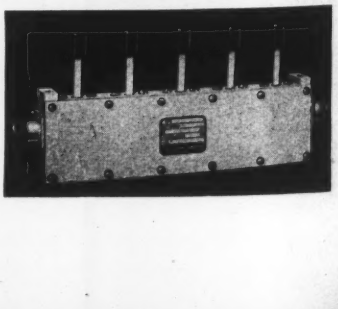
Recording Galvanometer

New "Model 8004" ink-writing galvanometer in conjunction with d-c. amplifier provides ink-record response of 0 to 400 cps. with tolerance of 20 percent. Chart speeds are from 0.1 to 625 mm./sec. Available with up to 24 channels. Sensitivities are up to 2 mv. per mm.—*Edin Co., Inc., 207 Main St., Worcester 8, Mass.*

Mention No. 336 when filling out card.

R-f. Attenuator

New "Series RF-550" r-f. attenuator has two units in series. Available with losses up to 100 db. in 1-db. steps. Units have zero insertion loss. Frequency range is from d.c. to 225 Mc. Standard



impedances are 50 and 73 ohms.—*Daven Co.*, 191 *Central Ave., Newark, N. J.*

Mention No. 337 when filling out card.

Airborne Receiver

New "Model AR-1" airborne receiver is 5-tube miniaturized superheterodyne broadcast receiver. Frequency range is 550-1700 kc.; sensitivity is better than 5 microvolts; i-f. frequency is 456 kc.; power is 0.625 amp. at 28 v. d.c. and 0.050 amp. at 250 v. d.c.—*Gertsch Products, Inc., Los Angeles, Calif.*

Mention No. 338 when filling out card.

Decade Scale Proportional Counter

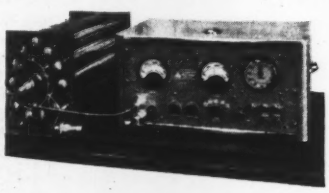
New "Model PC-3" counts alpha, beta, and gamma rays. Has rapid-reset six-digit register with coincidental reset

and switch; automatic gas purge cycle. Maximum counting rate is 1,000,000 c./m. Chambers accept sample up to 2.25-in. dia.—*Nuclear Measurements Corp., Indianapolis, Ind.*

Mention No. 339 when filling out card.

Age Measurement

New "Libby Carbon-14 Age Determination Machine" measures age of any historical artifact between 1,000 and 25,000 years old composed of organic



material. Apparatus consists of ring of 11 matched anti-coincidence counters, "Libby Screen Wall Counter," circuit containing separate voltage supplies for each set of counters, scale-of-two circuit, and Veeder-Root register with anti-coincidence circuit.—*Radiation Counter Laboratories, Inc.*, 5122 *W. Grove St., Skokie, Ill.*

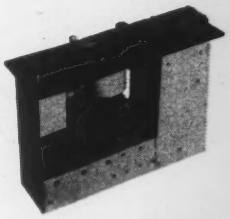
Mention No. 340 when filling out card.

Gamma-ray Counter Tube

New hydrogen-filled tubes detect gamma rays at counting rates of 500 to 1000 counts per second, under all atmospheric conditions, and over long periods of time. Outgassing technique eliminates effect of temperature variation from minus 40 to plus 300 deg. F. Operating voltage is 1075 v.; plateau is 300 v. Dimensions are 3.25 x

SANBORN
RECORDING EQUIPMENT

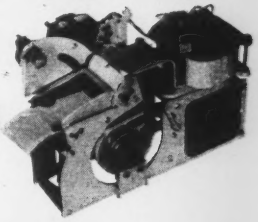
AMPLIFIERS



GENERAL PURPOSE—AC operated driver amplifiers; comprising three direct coupled push-pull stages.

STRAIN GAGE—Modulated carrier type for use with strain gage and resistance thermometer elements; strain gage, differential transformer, and variable reluctance transducers.

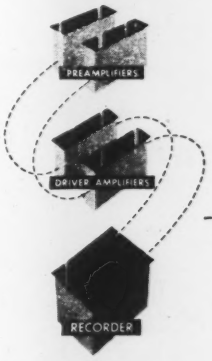
RECORDERS



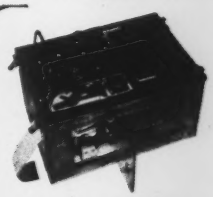
ONE-, TWO-, AND FOUR-CHANNEL. Permanent records produced by inkless, heated stylus on plastic coated paper in true rectangular coordinates. May be used in ANY position. Extremely rugged.

SEPARATELY or in COMBINATION

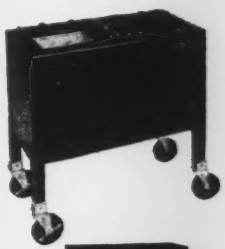
INTERCHANGEABILITY of Preamplifiers and Amplifiers permits recording of many different types of phenomena.



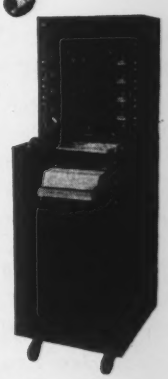
Any of the recording channels in the three systems at the right may include *either* a Strain Gage or General Purpose Amplifier, or the latter in combination (in 2-, and 4-channel systems) with either AC or DC Preamplifiers. For, any of the Amplifiers or Preamplifiers provided for in a system may be quickly *removed* from its place in the system and as quickly *replaced* with an alternate type.



SINGLE-CHANNEL Recording Systems—comprising *either* a General Purpose or Strain Gage Amplifier in combination with a one-channel Recorder Assembly. Standard paper speed at 25 mm/sec., slower speeds available. Paper width 6 cm with 5 cm recording area.



TWO-CHANNEL Recording System—Two channels operate independently of each other, but record simultaneously. Eight paper speeds. Timing and coding. Each channel 5 cm. recording width.

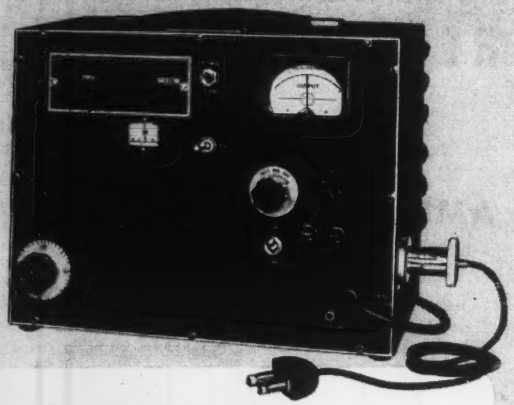


FOUR-CHANNEL Recording System—Up to four phenomena on one record, using the same principles and methods as the two systems above. Eight paper speeds. Provision for use of 4-, 2-, or 1-channel recording paper.

Write for completely descriptive, illustrated catalog.

SANBORN COMPANY
CAMBRIDGE 39 MASSACHUSETTS

FREQUENCY MODULATED SIGNAL GENERATOR



MODEL 78FM

86-108 MC

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1 to 100,000 MICROVOLTS

Variable Output

With Negligible Carrier Leakage

MODULATION: 400 cycle internal audio oscillator. Deviation directly calibrated: 0 to 30 kc. and 0 to 300 kc. Can be modulated from external audio source.

Audio fidelity is flat within 2 db from dc to 15,000 cycles. Distortion less than 1% at 75 kc. deviation.

The Model 78FM when used with Measurements Model M-275 Converter provides output in the IF ranges of 4.5, 10.7 and 21.7 mc.

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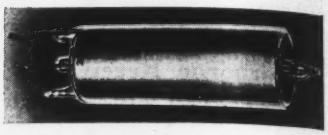
JOHN R. MONSELL

Manufacturing Engineer

Pitman, N. J.

NEW INSTRUMENTS



1.25 inches. As only one gas is used in filling, external quenching of ionization caused by gamma rays is used. One-gas filling overcomes disadvantage of multiple-gas filling in which one molecule of quenching gas is destroyed each time a gamma ray is detected. Tubes are sold to users.—*Instruments, Inc., 122 N. Madison St., Tulsa 6, Okla.*

Mention No. 341 when filling out card.

Radioactivity Survey Meter

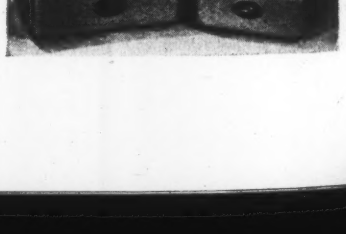
New "Raychronix Model D-3" portable survey meter measures low-level alpha or beta contamination on flat or irregular surfaces; is calibrated

0-500, 2500, and 12,500 alpha counts per minute. Corresponding gamma radiation ranges are 0-0.7, 3.5, and 17.5 mr./hr. Ionization chamber in bottom is used for table-top monitoring; external probe contains chamber and preamplifier for checking irregular surfaces. Drift in 8 hours is less than 10 percent scale.—*Radioactive Products, Inc., 443 W. Congress, Detroit 26, Mich.*

Mention No. 342 when filling out card.

Radioactivity Meter

New "Model AH-1 Gammometer" utilizes "Ohmart Cell" which detects radiation without high-voltage supply, and measures microcurie quantities. Maker's line of "Gammometers" now extends from 0.1 microcurie to 10 millicuries full scale, calibrated in terms of



radium iodine-131, or cobalt-60.—*The Ohmart Corp.*, 2351 *Ferguson Rd., Cincinnati* 38, *Ohio.*

Mention No. 343 when filling out card.

Beta Sources

New sets of five beta-emitting calibrated reference sources (made by Technical Operations Incorporated of Boston) comprise sources of: carbon-14, cobalt-60, thallium-204, bismuth-210 and protactinium-234. Beta energies range from 0.155 to 2.3 Mev. By comparison with these sources, it is possible to make millicurie determinations of beta-emitting radioisotopes. Mounts and copper disks are provided for such determinations.—*Atomic Instrument Co.*, 84 *Massachusetts Ave., Cambridge* 39, *Mass.*

Mention No. 344 when filling out card.

Testing Machine

New 350-lb.-capacity portable hydraulic compression machine applies load to specimen by compressed air. Double proving ring assures accuracy

in low range and obviates need of changing rings; when capacity of outer ring is reached, heavier inside ring is brought into action. Low-range sensitivity is 0.1 lb. Load can be released at any time. Light-weight air-storage tank is available where there is no regular air supply.—*Labquip Corp.*, 4520 *W. North Ave., Chicago* 39, *Ill.*

Mention No. 345 when filling out card.

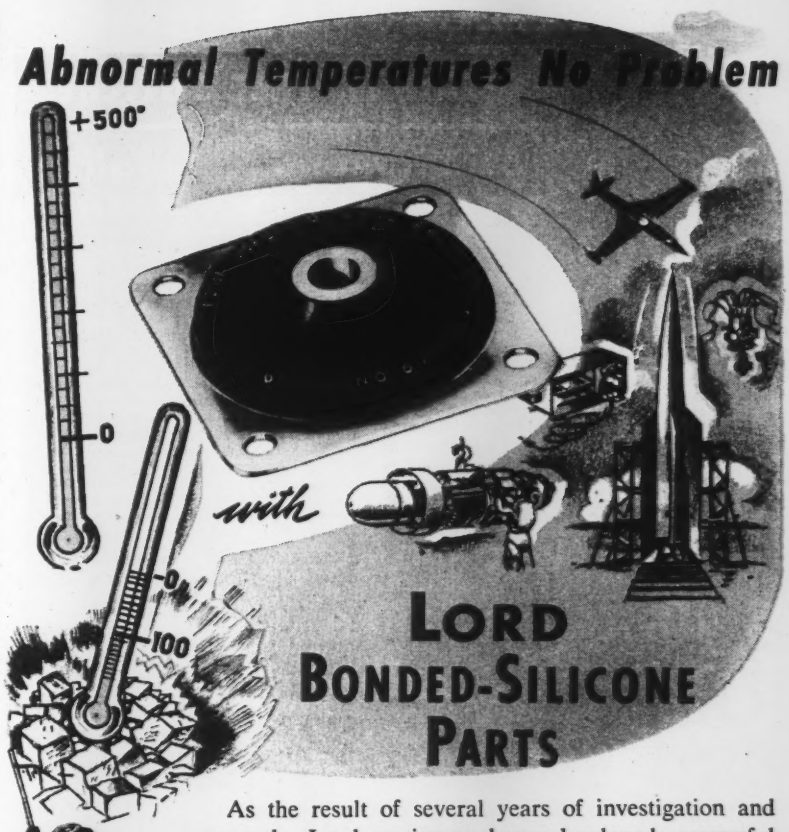
Reticles

New precision reticles contain lines as fine as 1 micron, with spacing as close as 5 microns. Manufacturing process uses microphotography. Reticles can be made in any size or shape. Average size for eyepiece reticles is 21 mm. circumference.—*Instruments Div., United States Testing Co., Inc.*, 1415 *Park Ave., Hoboken, N. J.*

Mention No. 346 when filling out card.

Projection Viewer

New "Series 13000 Beattie Projection Viewer" for data reduction and analysis accommodates 35-mm. single-frame or double-frame film in rolls and 70-mm. film in rolls. Projector head revolves 360 degrees to present image in cor-



As the result of several years of investigation and research, Lord engineers have developed successful techniques for bonding silicone to metal. This extends the advantages of bonded rubber into the wider temperature range from —100° to +500°F.

A number of Lord Vibration-Control Mountings are available with silicone elastomers, and new designs are being engineered to take full advantage of the properties of this new material.

You can solve many product problems with Lord bonded-silicone parts which are used to isolate vibration and reduce operating noise, and protect parts from excessive stresses.

The easiest way to get the full story of the advantages of LORD BONDED SILICONES is to write or call . . .

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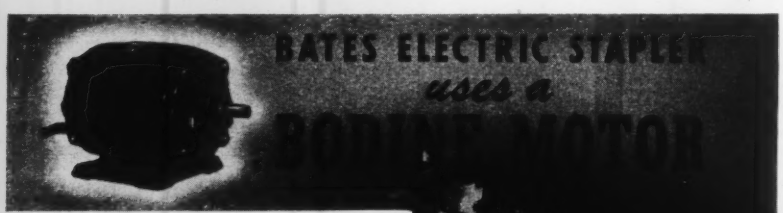


Such terms as hair-trigger, 5000 shots, jam-free, and easy to reload would seem to apply to some new deadly weapon or cereal premium rather than an electric stapler. However, the Bates Electric Stapler, powered by a compact Bodine motor, actually "shoots" staples into the paper when its edge touches the stapler's hair-trigger electric switch.

"After finishing the basic engineering work," states the Bates Manufacturing Co., "we contacted several motor manufacturers and found that Bodine made a motor which was most suitable for our requirements in that it was of the size we wanted, provided necessary power, had proper gear reduction, and was standard. Furthermore, Bodine was known to us as the best in the fractional horsepower motor field. The quality of these motors over the last 1½ years has proved to be consistently high from a performance and service standpoint."

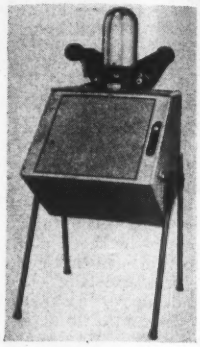
There are over 3500 standard Bodine motors. If you have a motor application problem, it will pay you to consult Bodine engineers.

Bodine Electric Co., 2244 W. Ohio St., Chicago 12, Ill.

BODINE
Fractional Hp Electric
MOTORS

THE POWER BEHIND THE LEADING PRODUCTS

NEW INSTRUMENTS

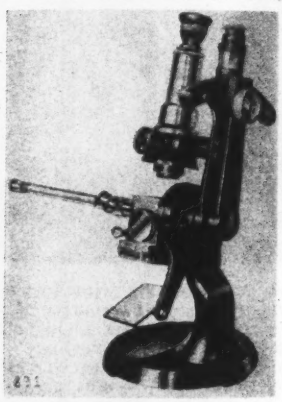


rect attitude. Normal film motion is single-frame and can be effected at two frames per second. High-speed rewinding in either direction. Screen is adjustable for height and angle of view.—*Photographic Products, Inc.*, 6916 *Romaine St., Hollywood* 38, *Calif.*

Mention No. 347 when filling out card.

Refractometer

New "Model WT-4" Abbe refractometer (Japanese-made) has *n* range from 1.3 to 1.7; temperature range from 0 to 100 C.; takes liquid, solid, and

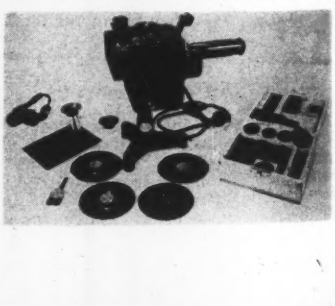


powdered samples. Accessories: case, monobrome naphthaline, test piece, thermometer, screwdriver, and dispersion table. Max error is 0.0002 for *n* and 0.0005 for average dispersion.—*Electro-Physics Co.*, 287 *Broadway, New York* 7, *N. Y.*

Mention No. 348 when filling out card.

Stroboscope

New "Kern Super-Stroboscope" (Swiss-made) permits observing and photographing periodic and aperiodic phenomena. Light from object is di-

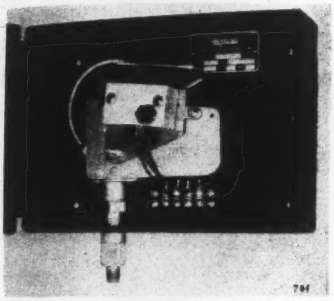


rected by a fixed mirror onto a mirror drum coupled to spindle which drives disk. At proper speed ratio of drum slit, stroboscopic images appear side by side on drum mirror. Greatest degree of subdivision is 4000 images per second. By stopping mirror drum, instrument becomes simple stroboscope. Motor speed is adjustable; speed is indicated on scale. Transmission ratio between 1:45 and 1:90 also is shown on scale. Instrument can be fitted for optical magnification and photography.—*Lovins Engineering Co., 8203 Cedar St., Silver Spring, Md.*

Mention No. 349 when filling out card.

Pressure Transmitter

New electromechanical instrument uses differential-transformer principle. Tip of Bourdon tube is rigidly connected to movable armature in transformer

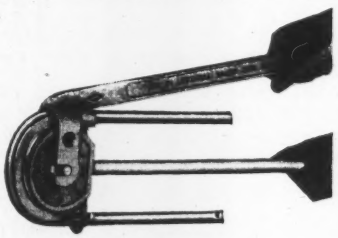


coil. Pressure causes motion of armature and electric signal is generated proportional to amount of travel. Accuracy in standard ranges from 15 to 5000 psi. is 0.25 percent of full range. Bourdon tubes are "K" Monel.—*Automatic Temperature Control Co., Inc., 5200 Pulaski Ave., Philadelphia 44, Penna.*

Mention No. 350 when filling out card.

Tube Bender

New "No. 362-F" combination tube bender bends both ½ in. and ⅝ in. O.D. copper, aluminum, brass, and other soft, thin-wall metal tubing; is of two-



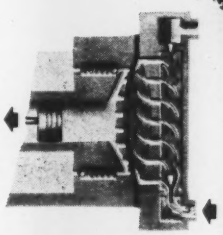
piece construction and quickly comes apart to slip over tube at point where bend is needed.—*The Imperial Brass Mfg. Co., 1200 W. Harrison St., Chicago 7, Ill.*

Mention No. 351 when filling out card.

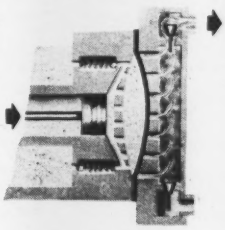
Film-casting Knife

New casting knife is for applying uniform coating of film on plane surfaces. Consists of blade controlled by two micrometers, with well for holding

Lapp
Auto-Pneumatic
PULSAFEEDER



INTAKE STROKE



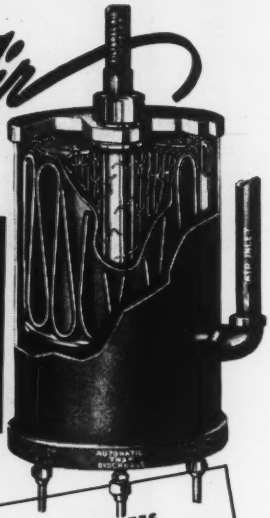
DISCHARGE STROKE

No packing or other leak-likely gland can be in contact with chemical being handled by the Lapp Pulsafeeder. A hydraulically-balanced diaphragm acts as a floating partition, without mechanical load or pressure differential—assures isolation of chemicals being pumped from all working pump parts. Pumps against pressures to 2,000 lbs., at constant pumping speed—variable flow for continuous processing results from variation in piston-stroke length-controlled by instrument air pressure responding to any instrument-measurable processing variable.

WRITE FOR NEW BULLETIN No. 300, just issued. 24 pages of description, specifications, typical applications, flow charts. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 569 Maple Street, Le Roy, N. Y.

NOW ··· Clean, Dry Compressed Air —for Operating Instruments!

The NEW Model B-30 HANKISON Condensifilter



For maximum protection of air-operated instruments against oil, water, sludge and foreign materials, the New Hankison Model B-30 Condensifilter features a dehydrating device—a mechanical filter—and a self-purging trap in a single compact unit. Only 15" high and 9" in diameter, this unit will clean and dry compressed air at the rate of 30 c.f.m. at 100 psi. Larger models available for greater capacities.

To add long life and trouble-free service to your air-operated instruments—specify B-30 Condensifilters for your requirements.

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HOW IT OPERATES

Compressed air is dried as it crosses coils . . . condensate drops into automatic trap below. Dried air is then cleaned through seven layers of canton flannel, and passed through shaft to the instrument air lines.

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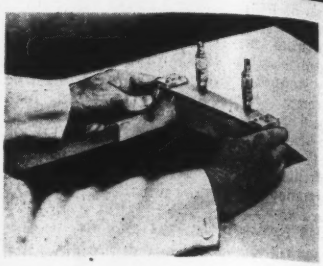
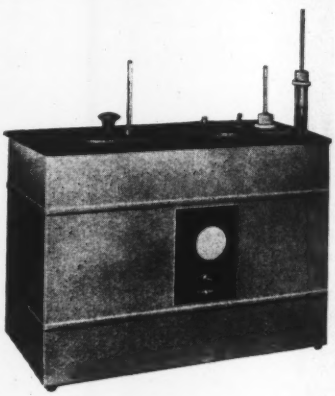


paint, plastic, or other coating material. —*Gardner Laboratory, Inc., Bethesda 14, Md.*

Mention No. 352 when filling out card.

Refrigeration Bath

New "Frigistat" bath is designed for A.S.T.M. Method D97 (cloud and pour test). Although manually operated, it can be maintained within 2 deg. F.

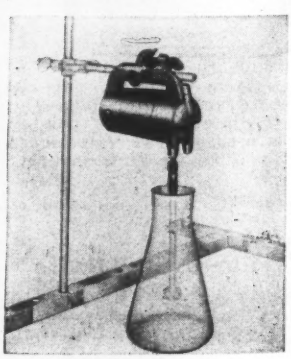


Seven-unit test chamber and dry-ice chamber are well insulated. Cooling medium is circulated in test chamber through coils which do not allow interchange of fluid between chambers. Overall dimensions: 24.5 by 13 by 18 in.—*Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.*

Mention No. 353 when filling out card.

Three-speed Stirrer

New "Mighty Midget" is 300, 600, and 900 rpm. stirrer with 1/16-hp. series-wound motor. Bracket permits mounting in any position. In normal po-



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sition, center of gravity is below support rod to prevent accidental turnovers and breakage of beakers.—*Laboratory Industries, Inc.*, 4710 *W. North Ave., Chicago* 39, *Ill.*

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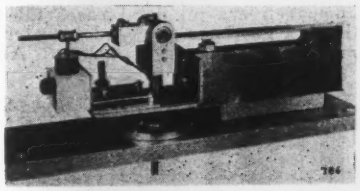
Cantilever-beam Load Cell

New instrument for changing mechanical force into proportional electrical signal operates on cantilever-beam principle. Motion of beam moves



armature in linear transducer. Up to four cells can be connected mechanically to a single platform for scale applications. Accuracy is ¼ percent full range. Available in ranges from 5 to 500 lbs.—*Automatic Temperature Control Co., Inc.*, 5200 *Pulaski Ave., Philadelphia* 44, *Penna.*

Mention No. 355 when filling out card.

Toroidal-core Transformer

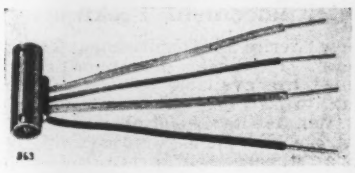
New "Type 942-A" output transformer provides eighteen impedance ratios. Tight coupling permits feedback with low phase shift. At continuous

power of 90 watts, transformer distortion is 1 percent or less above 30 cps. Upper frequency limit is between 50 and 100 kc. depending on connections used.—*General Radio Co.*, 275 *Massachusetts Ave., Cambridge* 39, *Mass.*

Mention No. 356 when filling out card.

Instrument Rectifiers

New "Minisel" instrument rectifiers, said to be first made with selenium rectifier cells, have high blocking resistance, low conducting resistance, and



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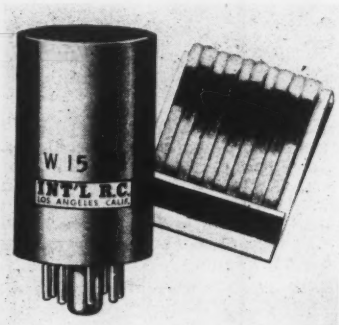
NEW INSTRUMENTS

long life. Available in half-wave, center-tap, doubler, and bridge arrangements. Cells are rated at 10 v. a-c. input and 5-ma. d-c. output.—*Electronic Devices, Inc., Precision Rectifier Div.*, 429 12*th St., Brooklyn, N. Y.*

Mention No. 357 when filling out card.

Selenium Rectifiers

New line of hermetically-sealed selenium rectifiers in metal cases filled with inert gas have standard tube terminals to fit standard sockets. All

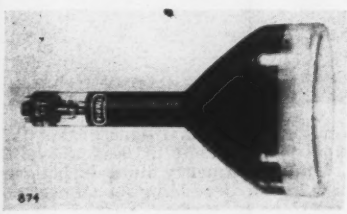


standard tube mountings available. Unit illustrated (No. W15CM) is rated at 390 volts rms. input; 550 volts peak inverse; 120 ma. 160 volts d-c. output at 35 deg. C. ambient. Half-wave and bridge circuits also available.—*International Rectifier Corp.*, 1521 *E. Grand Ave., El Segundo, Calif.*

Mention No. 358 when filling out card.

Oscillograph Tube

New "7MP14" is 7-inch cathode-ray tube of magnetic-deflection and magnetic-focus type with medium-long-persistence, cascade (two-layer) screen.



Intended for oscillographic applications, such as radar indicator service, where grid 1 is pulse modulated. Can be operated with scanning frequencies as low as 30 cps. without excessive flicker.—*Tube Dept., Radio Corp. of America, Harrison, N. J.*

Mention No. 359 when filling out card.

Displacement Pickups

New "Series 211 Displacement Transducers" (rectilinear potentiometer resistors) are available in strokes from 0.2 in. to 5.75 in., with resistance values from 100 to 15,000 ohms per inch of stroke. For strokes up to 0.75 in., spring-returned shafts are available,

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From less than 1 up to 10,000 psi, with various types of resistance and inductive output values, Giannini precision pressure transmitters are designed to withstand extremes of acceleration, temperature, vibration, while at the same time retaining their accuracy and their fast response characteristics. "They are standard with the Leaders." Write for booklet.

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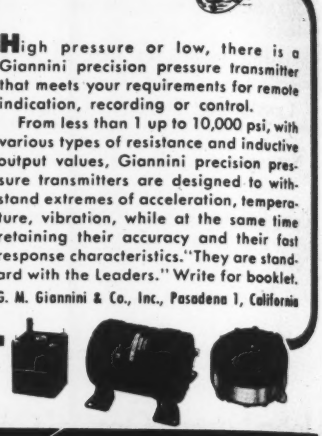

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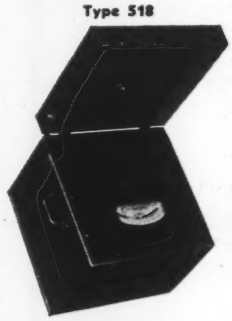
Type 518



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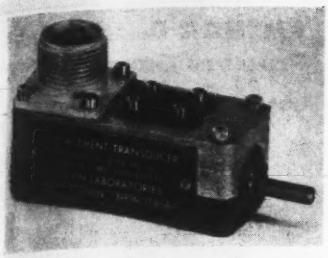
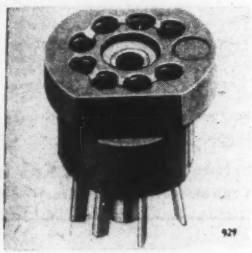


threaded shafts being offered on all stroke lengths. Simple rugged construction assures long life. Linearity is 0.5 percent or better on units having strokes of 0.75 in. or more.—*Colvin Laboratories, 12 Court St., Morristown, N. J.*

Mention No. 360 when filling out card.

Subminiature Sockets

New subminiature tube sockets mount without screws or rivets in shaped chassis holes. Material is "Mycalex 410." Available with cadmium-plated brass

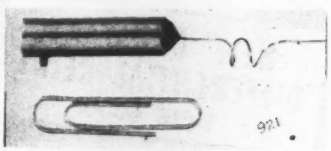


contact terminals or silver-plated beryllium copper terminals (others on special order).—*Mycalex Tube Socket Corp., 30 Rockefeller Plaza, New York 20, N. Y.*

Mention No. 361 when filling out card.

Miniature Thermostat

New miniature adjustable metal-enclosed thermostat has a temperature range from minus 50 to plus 350 deg. F. and is adjustable plus or minus 60 deg. F. from factory setting. Stability



is achieved by use of ceramic bushing to anchor bimetal and by separate phosphor-bronze spring to prevent bimetal from taking a set or becoming overstressed. Contacts are rated at 1 amp., 115 v. a.c. or 0.5 amp., 115 v. d.c. Shell length is 1.25 in.; diam. is 0.31 in.—*Instrument Div., Thomas A. Edison, Inc., West Orange, N. J.*

Mention No. 362 when filling out card.

Sensitive Relay

New "Type N" relay operates on less than 50 milliwatts with 10,000-ohm coil and one SPDT contact. With 450-ohm coil and four 4PDT contacts, it operates

when timing poses a problem it's time to consult the **A. W. HAYDON** *company*

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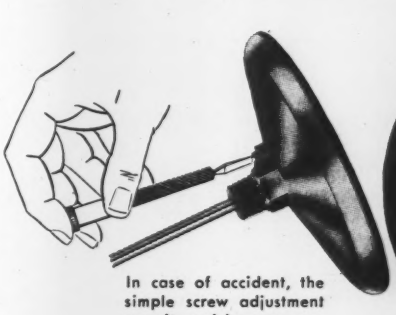

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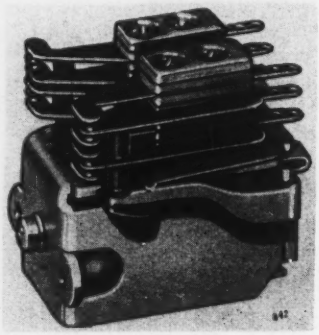
NEW INSTRUMENTS

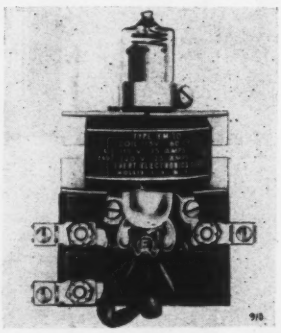


on 0.7 watt. Sensitivity results from close-coupled magnetic circuit. Contact pressure is above 30 gm. Relays are compact and have maximum of ten contact springs. Can be hermetically sealed. —*C. P. Clare & Co.*, 4719 *W. Sunnyside Ave., Chicago* 30, *Ill.*

Mention No. 363 when filling out card.

Three-wire Relay

New "Model EM-10" mercury plunger relay has three-wire operation. When

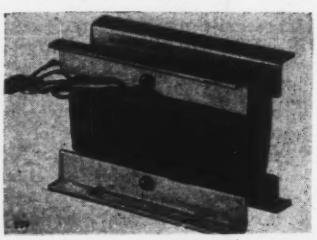


contact is made, input line connects to two isolated circuits. Loads to 35 amp. at 115 volts a.c. or 25 amp. at 220 volts d.c. can be handled.—*Ebert Electronics Co.*, 185-09 *Jamaica Ave., Hollis, Long Island, N. Y.*

Mention No. 364 when filling out card.

Saturable Transformers

New line of saturable transformers meets military specifications. Power output is phase-reversible a.c. with output

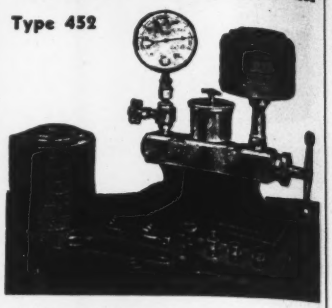


of one watt to one kilowatt, both 60 and 400 cps. Open type and hermetically sealed units available.—*Magnetic Amplifiers, Inc.*, 11-54 44*th Dr., Long Island City* 1, *N. Y.*

Mention No. 365 when filling out card.

AMTHOR Dead Weight Pressure Gauge TESTER

Type 452



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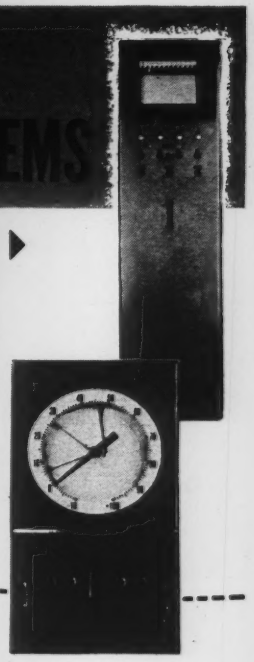

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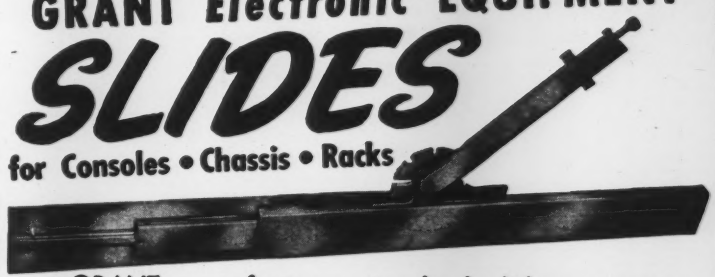

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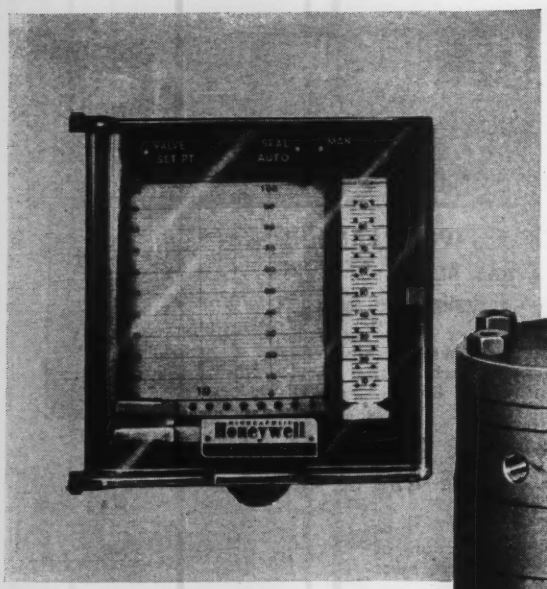
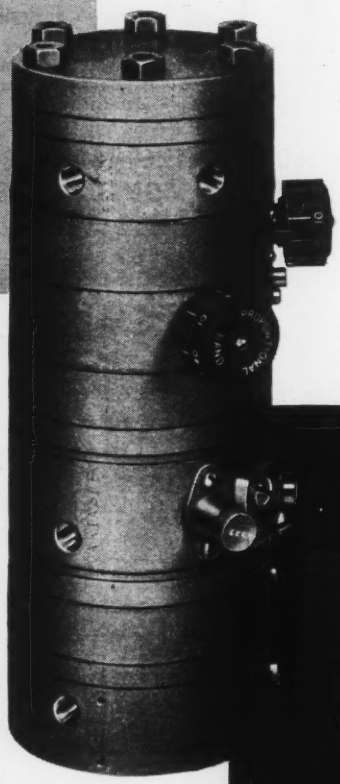


TEL-O-SET RECORDER

Features withdrawal of chassis for full 8-hour chart visibility without interrupting operations, bumpless shifting from automatic to manual operation, all adjustments from front of panel, built-in adjustable restrictions for pulsating flow . . . requires panel space just $5\frac{1}{16}$" high by 5" wide. Write for Specification Sheet No. 769.



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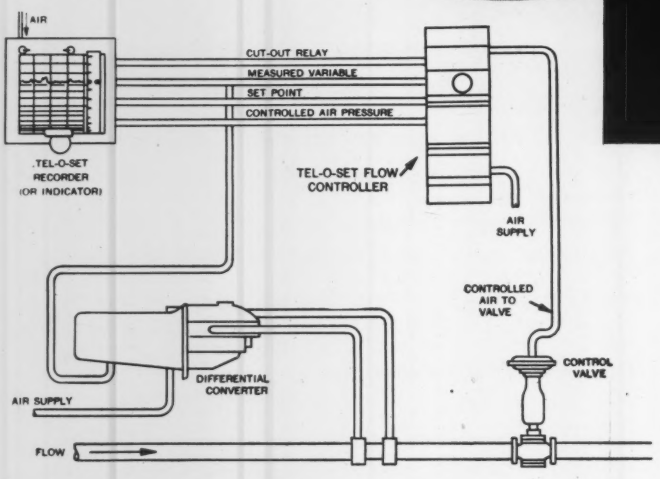
Available in adjustable and fixed proportional band models, and with three control forms . . . for flow, temperature, pressure, level and other process variables. Universal bracket permits optimum flexibility in mounting . . . coded, interchangeable sections and split manifold contribute to simplified maintenance. Write for Specification Sheet No. 768.



TYPICAL ENGINEERED *TEL-O-SET* CONTROL SYSTEM — Pictured in this diagram are the elements of the *Tel-O-Set* Family, designed and built as an integrated loop. Here the system is applied to the control of flow with the *Differential Converter* used as transmitter.

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Can be used with any pneumatic transmitter, having a 3-15 psi controlled air output, regardless of the primary element being used. Provides indication of process variable, set-point of controller or controlled air pressure to valve when on automatic control . . . is easily shifted to manual operation. Panel cut-out size same as recorder. Write for Specification Sheet No. 770.

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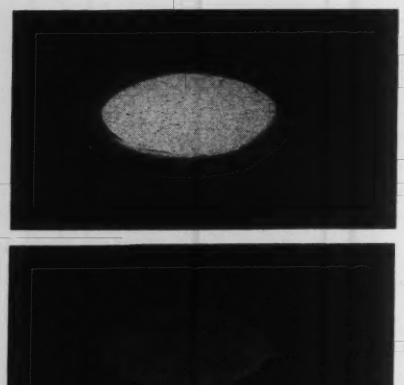

Pool of clean mercury shows perfect reflecting surface; adding a tiny particle of lead-zinc alloy (contamination of 4 to 5 parts in a million) causes contamination shown below.

MERCURY

The Purest Metal

By J. B. LAWRENCE,
Bethlehem Apparatus Co.

When is mercury clean? How is mercury cleaned? Why does skin reform on "clean" mercury? Herein are the answers to these common and important questions.

IF a metallurgist were asked which metals have been refined to the purest state, he probably would reply that laboratory specimens of iron have been produced with impurities of only one or two hundredths of one percent, that copper has been refined even further, that "four nine" zinc (99.99 percent pure) is sold commercially, and that "five nine" zinc is obtainable. It is likely that he would overlook the purest metal of all—mercury.

Whereas "five nine" zinc, with only one part impurity in a million, represents the highest grade for that metal, this figure represents the poorest that can be regarded as high grade for mercury. Moreover, whereas high-purity iron, copper, and zinc are required for only exceptional purposes, the opposite is true of mercury. As sold commercially it is undoubtedly the purest known substance; to render it suitable for many important uses it must be purified still further. For certain applications the impurity must not exceed a few parts in a billion. And in contrast with other metals which can be analyzed only by chemical methods, the purity of mercury can be judged closely merely by visual inspection—to as close as one or two parts in ten million.[1]

Prime Virgin

The appearance of mercury as it is poured from the customary iron flask—covered with iron rust, greasy sulphide ("stupp"), and dirty water—suggests a crude product; but this is far from true. Beneath the surface, mercury is likely to be entirely clean, especially if it has come from sources where the ore is free of contaminating metals. The current increase in price has caused the opening of many new mines, some with ore containing lead, cadmium, and zinc. As the extraction process consists simply of roasting the sulphide ore (cinnabar) in air and condensing the mercury vapor, any easily volatilized metals are carried over and foul the product. The term "Prime Virgin," which is applied to the metal shipped from the mines, does not refer to the purity. One large manufacturer of flowmeters found cadmium contamination as high as 0.1 percent. Such a tremendous amount of impurity rendered the product unfit for use.

Surface Tension

Mercury has high surface tension. This is why a droplet of mercury maintains a spherical shape. When mercury is in contact with nonmetallic materials, the surface tension is high enough to cause the mercury to pull away from the material and try to form a sphere. Hence mercury does not "wet" nonmetallic materials, but forms a convex meniscus when in contact with them.

Dust and dirt adhere tenaciously to the surface of mercury. A surface layer of dust and dirt can prevent droplets from joining together into a pool. However, dust does not interfere with the tendency of a mercury drop to form a sphere, as does oxide skin.

Oxide Skin

Although mercury is obtainable in a pure state, contamination is difficult to avoid. Base metals such as lead, tin, zinc, and cadmium dissolve readily in mercury; copper and aluminum also dissolve, although more slowly. These metals form oxide skins on the surface, destroying mercury's bright appearance and causing it to "tail" and stick to glass (Fig. 1).

When base metals are dissolved in mercury, the oxides of the dissolved metals stick to any surface and cause dirty rings to form. The mercury then wets the walls of vessels because its surface tension is lowered. This can be seen by comparing drops of clean and dirty mercury. The former are bright and stand up in spherical form, whereas the latter are dull and lie flat and lifeless. If an oxide skin is removed by skimming, it reforms because the atoms of the base metal oxidize as they reach the surface. This experiment can be repeated indefinitely.

Strangely enough, the types of impurities and the characteristics of pure mercury are not well understood by people who work with the metal. For example, the question often is asked: "How long does it take for the oxide skin to form on the mercury?" The answer is that pure mercury does not form an oxide skin at all, regardless of how long it is stored. A curious misconception of this fact is found in recommendations frequently given on the use of the McLeod gage. It is stated that the air used for raising and lowering column should be dried by inserting in the line a series of drying tubes, or that nitrogen should be substituted for air—all for the purpose of preventing the lower bulb from being covered with a layer of "crut." These recommendations are useless because if base metals are present in the mercury, such precautions are ineffective; if the mercury is pure, as it should be, they are superfluous.

Purity Tests

Many buyers of mercury, aware that

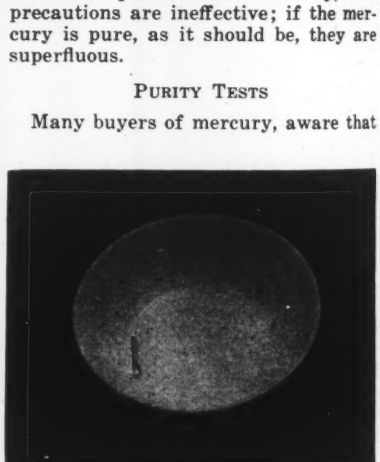

Fig. 1. The "Swirl Test" for mercury; base-metal contamination causes "tailing" as shown.

only the cleanest mercury is suitable for instrument use, have relied on three standard tests—the American Dental Association (A.D.A.), the United States Pharmacopeia, (U.S.P.), and the American Chemical Society (A.C.S.).

The U.S.P.[2] directs that 5 grams of mercury, 5 c.c. of nitric acid, and 3 c.c. of water be evaporated on a water bath and the residue ignited and weighed. The weight must be less than 0.01 percent of the mercury weight. The A.D.A.[3] chemical specification directs that a weight of from 10 to 15 grams be evaporated in air and then ignited. The residue must be less than 0.02 percent.

Experience demonstrates that these tests, although applicable to mercury as a chemical reagent, fall short when used as a means of determining its suitability for instrumentation. This can be verified by adding the minimum percentage of lead, tin, solder, or similar metal to pure mercury. When the contaminating metal is dissolved in the mercury, the mirror-like surface disappears and is replaced by a wrinkled skin which sticks to the receptacle and turns black on the surface.

A fourth test sometimes employed is the *spectrochemical test.* The spectroscope is regarded by many as the most delicate detector of minute traces of elements. However, mercury that is "spectrochemically pure" can contain damaging amounts of contaminating metals.

A test recommended by Dr. Wichers[7], which is far better than those mentioned previously, is in general use for special applications, as in thermometers. This test consists merely of placing a globule of mercury in a clean porcelain dish and gently swirling it around (Fig. 1). If it runs freely, without leaving any tail, it has the necessary purity. The A.C.S. test[4] for base metals is similar. Ten to twenty grams of mercury are evaporated on a hot plate without boiling, during which operation the mercury must retain its bright surface and not develop any film or scum. The accuracy of these tests far exceeds the chemical methods, being sensitive to as little as one or two parts in ten million. They cannot, of course, detect the presence of noble metals, which do not cause fouling of the mercury. The only other test exceeding the Wichers and A.C.S. tests in accuracy is an electrical method[5], applicable only to zinc, which is said to detect one part in ten billion.

Properties

There are many properties of mercury which make it valuable. It is liquid from minus 38.9 deg. C. to plus 357 deg. C., within which range exist customary laboratory temperatures. It is a noble metal in that it is not oxidized by air or oxygen at room temperature. Its density is high—about 13.5—and its vapor pressure is low—less than two microns at room temperature. A most useful property is its insolubility for most gases, an unusual characteristic because many other metals in liquid state absorb large quantities of gas. For example, liquid iron absorbs hydrogen, copper absorbs oxygen, etc. A spectacular proof of the insolubility of gases in mercury is that some Bureau of Standard's barometers possessed the same accuracy as new barometers after 25 years of observation.

Mercury, like water, has practical uses in all three states—solid, liquid, and vapor; it exceeds any other metal in the diversity of its uses. Most of the vast wealth buried at Fort Knox has been captured by mercury in the sluice-boxes and on the plates of gold mines. The most efficient source of power today is the mercury boiler. Some gasoline is refined by the heat of mercury vapor. Mercury vapor carries the current in rectifiers, and gives off the luminescence of high-intensity arc and sun-tan lamps. In diffusion pumps, mercury vapor produces vacuums of the highest order. A recent use of an isotope of mercury is the use of one of its spectral lines as the "ultimate" standard of length.

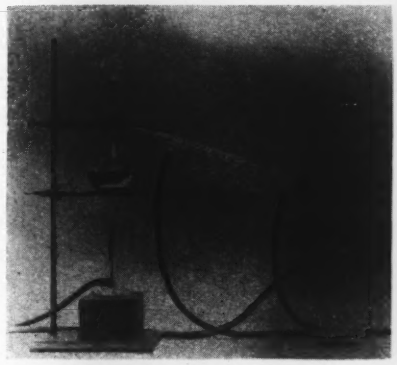

Fig. 2. The Hulett still.

Mercury alloy has wide use as dental amalgam. For many centuries it was a reflecting surface of mirrors. In liquid form it measures temperature, pressure, and density. It makes electric contacts in switches and thermostats. It performs a variety of useful functions in instruments and commercial processes, including the polarograph, the cathode cell, and electrolytic production of soda. In solid form it is the basis of the new and promising frozen-mercury casting process. It has an important scientific use as the basic standard of resistance —the ohm being defined as the resistance of a column of mercury of a certain cross section and length. Mercury in standard cells is used in all types of potentiometers. In the latter two applications, purity is the basic requirement.

There is growing appreciation of the need for pure mercury. Although purity always has been regarded important for certain specific uses, the interest is extending to fields where formerly the purity of mercury was not considered.

Filtering

Among the oldest cleaning methods is squeezing through leather, mentioned by the historian Pliny. Chamois skin still is employed for that purpose. A device popular in gold mines consists of a chamois-skin bag which can be squeezed between rollers. Such a method, of course, removes only fine gold particles and floating dirt.

In laboratories, a glass funnel and filter paper with a hole punched in the tip has had wide use; if mercury is poured slowly, and a final portion left in the paper, most surface impurities are removed, including the skin of base-metal oxides. These oxides, of course, will re-form because base metals are still in solution. A similar and perhaps more thorough result is obtained if the mercury is poured over an inclined rough surface, a method covered by a German patent[6]. A filter made of fritted glass also has been designed[7]. For large quantities, a separatory funnel is reasonably effective if carefully handled. For removing oil, shaking with kerosene or a volatile solvent is common practice. If the mercury is wet, heat or charcoal will dry it.

Removing Dissolved Base Metals

Distillation

The removal of dissolved base metals from mercury is more difficult than filtering floating impurities. As mercury volatilizes at a lower temperature than its constituents, distillation has been standard procedure. Originally, distillation was performed at atmospheric pressure, as it still is at mines, but it was found long ago to be inefficient. V. Meyer[8] discovered that mercury retained traces of bismuth, lead, copper, tin, and other metals even after twelve such distillations. Such residues are caused partially by the small but appreciable vapor pressure of the base metals at the distilling temperature; but they are caused mainly by boiling of the mercury, resulting in a fine spray of droplets carried over with the vapor.

Vacuum distillation permits distillation at a much lower temperature, although great care must be exercised to prevent "bumping," which invariably causes a carry-over of base metals. This is especially hard to avoid in "mass" distillation—that is, where several hundred pounds are evaporated in a single operation. The heat must be regulated so that the rate of evaporation is slow.

Many forms of stills have been devised. Although most stills are merely ingenious arrangements of similar elements, an improvement suggested by Hulett[5] involves a new principle. In the Hulett still (Fig. 2), a tube drawn to a small aperture at the bottom dips below the surface of the mercury in the heating flask. An applied vacuum pulls a small but steady stream of air, which bubbles through and mixes with the mercury vapor. This not only prevents violent bumping, but tends to oxidize base metals. Cadmium and zinc, whose vapor pressures make them particularly difficult to remove in the ordinary still, are eliminated thoroughly. The method

is less effective with noble metals—Hulett recommends at least three distillations for silver. It is the author's opinion that this difficulty is due chiefly to the spray caused by breaking of the air bubbles at the mercury surface. In the laboratory of one large university the vapor was passed through a trap which, although decreasing the speed of distillation, resulted in a better product.

The problem of bumping has been attacked from another angle in the recently developed Eberbach still (Fig. 3).[9] The heating is by induction, which also causes a continuous swirling of the mercury mass. The still is large and is equipped with electronic control of the mercury level, permitting automatic operation. It is said to produce more than five pounds per hour.

Chemical Methods

The disadvantages of distillation—slowness, necessity for repetition, and frequent unsatisfactory results—have led to the use of many chemical methods for cleaning mercury. The first significant advance in this direction was the *nitric acid tower* developed by L. Meyer.[10] Mercury falls from a small orifice in fine droplets through a tall column of 5-percent nitric acid, with a gooseneck acting as a mercury trap at the bottom. Hildebrand[11] improved on this by squirting the mercury through a cloth to obtain a finer and more copious spray. The F. Friederich's tower[12] (Fig. 4) is indented to cause the droplets to take a slower zigzag course by striking numerous shoulders on opposite sides of the tower. A number of passes through the column are necessary; but the number cannot be large because mercury is slightly soluble in the acid, which leads to the accumulation of nitrate of mercury in the column. It is reported[13] that 3 to 9 percent of the mercury is attacked after three passes, and the solution should therefore be saved for future treatment.

Suction, air pressure, and other means have been used in attempts to make the process more automatic by returning the mercury to the top for repeated treatment. Unfortunately, no practicable way has been found to make certain that all portions of the mercury receive an equal number of passes through the still. This can be achieved only by allowing an entire batch of mercury to pass through the tower, and then repeating the operation, whether the process is manual or automatic. As acid, in spite of the mercury trap, gets through into the treated product (drops of it can be seen on the surface), it is necessary to wash the mercury several times by shaking it with distilled water, after which it must be dried. Following such treatment, mercury is bright and lively. However, if oxide skin begins to form after standing, further treatment is required.

Chemicals other than nitric acid are recommended, the mercury being shaken up or brought into contact with these solutions for extended periods. One recommendated chemical is five grams of potassium dichromate in a liter of water acidified with a few c.c. of sulphuric acid; another is hydrochloric acid with one-eighth volume of sulphurous; a third is dilute solution of potassium cyanide in the presence of sodium peroxide.[14] This last is claimed to remove gold, zinc, tin, lead, copper, and iron, and to produce mercury of higher purity than is possible with fractional distillation. Hanke and Johnson[15], who have investigated chemical methods of cleaning, have concluded that an electrolytic method is "the most satisfactory in combining effectiveness and convenience." They have worked out the following method of cleaning a batch of 15 pounds of mercury: The batch is placed in a bottle provided with

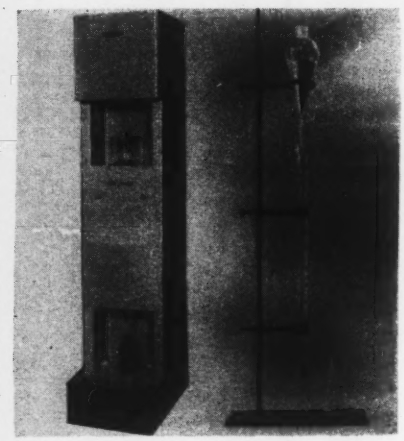

Fig. 3. (Left) The Eberbach still. Fig. 4. (Right) The Friederichs nitric-acid tower.

electrodes and a tube for bubbling air, with an equal volume of a 10-percent solution of sulphuric acid. The mercury is the positive pole, the acid the negative, and a 110-volt direct current is applied for fifteen minutes. The mercury then is washed by agitation with caustic and distilled water. A second electrode treatment follows, using sodium chloride instead of sulphuric acid. It then is washed. A third electrolytic treatment is applied with sulphuric acid, but with poles reversed. Then it is washed again with caustic and distilled water, treated with dilute nitric acid to remove surface scum, washed by dropping through a tall column of distilled water and, finally, dried with filter paper. A purity equal to the purest reagent mercury is claimed.

Oxidation

As oxygen combines with all objectionable base-metal impurities, and as oxygen at room temperature does not attack mercury, various schemes have been devised for oxidizing the impurities. W. R. Forbes[16] has employed charcoal saturated with oxygen gas to bring the metal in contact with the gas. A small quantity of mercury can be cleaned by placing it in a tube and bubbling oxygen through it[17]. The process has been used on a large scale by placing a number of flasks in series and bubbling with compressed air. Sometimes a little water or acid is added. The major drawback to this method is the time required. Hulett reports that a cadmium impurity of one part in ten thousand was not entirely removed in four days, but the author has observed instances where a complete cleanup was accomplished in three days. The time is required because the bubbles are large and the total surface area is small.

A method of overcoming this difficulty has been developed in the "Bethlehem Oxifier" (Fig. 5). The tightly closed cylindrical case is half-filled with mercury, which is then agitated by paddles mounted on a horizontal shaft. The operation breaks the mercury into a fine spray, which is brought into intimate contact with the air in the cylindrical case. Mercury is forced through air, rather than air through mercury. As the droplets are of minute size, the total surface area is large and oxidation is accomplished rapidly. The paddles also break up the oxide skin as it is formed, carrying it into and through the mass of mercury and releasing droplets entrapped in the scum. For light contamination the air in the cylindrical case is sufficient for complete oxidation of the charge; but for heavy contamination this air is quickly exhausted—if tested, the air will not support a flame. Thus, means are provided for renewal of the air.

Illustrating the highly effective action of oxygen as a purifier, it is found that after mercury has been oxified for about two hours, all base metals are changed to fine oxide powder which floats on the surface. Further operation has no effect.

Following all dry-cleaning methods—bubbling, oxifying, distillation, or any other—the surface oxides, or the "distillation scum," must be removed. Various methods of doing this already have been mentioned, but a more effective and convenient device is the "gold-adhesion" filter (Fig. 6)[18]. This filter is based on the fact that mercury wets

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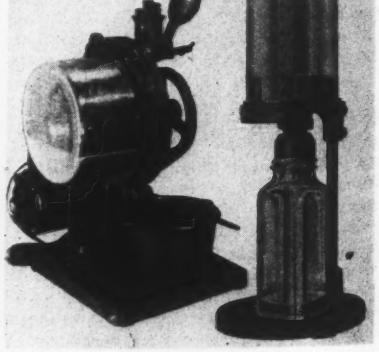
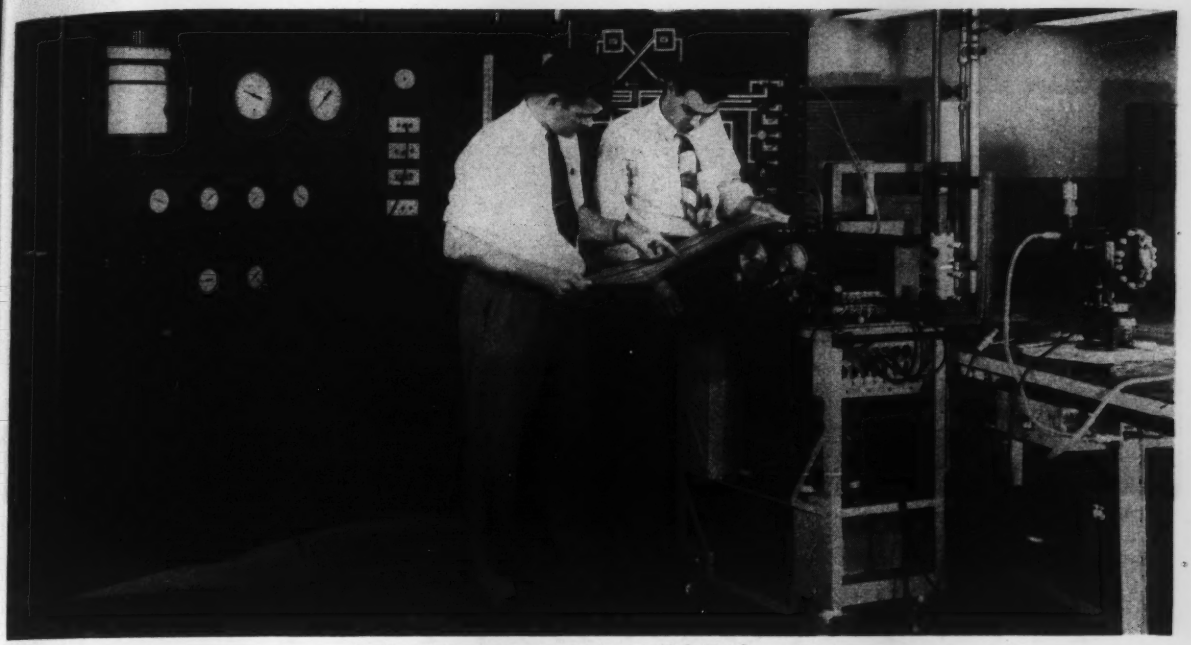


Fig. 5. (Left) The Bethlehem mercury oxifier. Fig. 6. (Right) The gold-adhesion filter.



Equipment for instrument testing at Shell Development

Evaluation of Plant-control Instruments

By A. BREMER and B. D. STANTON, Shell Development Company, Emeryville, Calif.

A large user of process instruments has this continuous program for analyzing commercial products

FOR the past several years there has been tremendous growth in the manufacture and application of instruments for plant control. Although the post-war expansion of many industrial plants can account for much of this growth, the fact that industry is becoming more and more instrument conscious may account for an even bigger share. With the flood of new instruments on the market there is always some doubt as to which is best for a particular control problem.

A need for more and better information on control instruments as they are placed on the market resulted in the formation of an instrument-testing group in the Shell Development Company. The primary purpose of this group is to procure standard production units from the manufacturers as soon as they are released, and obtain information about their characteristics, operation, and limitations. This information is reported to the instrument engineers in the Shell operating companies to familiarize them with the latest developments and to assist them in evaluating such equipment for new or existing installations.

As the tests are completed and a report is written on a specific instrument, the results are also sent to the manufacturer. This serves a secondary purpose; namely, the improvement in instrument design by the manufacturer when definite faults or limitations are discovered. In special cases design modifications have been suggested by the Shell Development group and subsequently incorporated into standard production items.

A third function of the Instrument Testing section is the complete design and construction of a working model of special control instruments which are not commercially available. These instruments may be specially made for one particular job and find no widespread application, or they may be developed for general use and licensed to one of the instrument companies for further promotion.

The first tests performed in 1947 consisted principally of dial calibrations and the determination of accuracy, linearity, and hysteresis of the control functions. Later a constant-temperature box was constructed for determining the effect of ambient temperature changes on transmitters and controllers. As testing methods were improved, the study was extended to (1) pilot-valve analyses and (2) instrument response to step-type changes in order to determine dead time and speed of response.

Test Panel

A test panel was designed and constructed as an aid in testing instruments in the laboratory and as a preliminary model of a unit which could be used to good advantage in the refinery and chemical-plant instrument shops. The original panel has been altered several times and has not been finalized as yet. Information obtained from its constant use, however, has resulted in the design of a small bench-size test-panel for instrument shop use in the Shell Companies.

The large panel consists basically of six precision pressure regulators and various means of duplicating process variables. Through snap-type fittings, controlled air at high or low pressure can be routed through different-size resistances and capacities, or even through a complete flow control circuit. Other features of the panel include test gages, mercury and water manometers, a stop clock, and a strip-chart recorder.

During the past year more and more attention has been directed toward dynamic characteristics of process-control instruments. For the study of amplitude ratio and phase-shift characteristics, two types of multi-channel high-speed recorders have been placed in service at the Shell Development Laboratory. All new instruments which are now obtained for evaluation are subjected to a thorough frequency-response testing program.

In order to obtain more data on actual control processes, the testing group has also been conducting field tests at some of the Shell refineries.

Control of polymerization of components is directed from the main control panel of one of the nation's largest synthetic-rubber plants.

INSTRUMENTATION of a Synthetic-Rubber Plant

By J. S. DETWILER
Taylor Instrument Companies

Editors Note: This is the second and final installment of Mr. Detwiler's article. The first installment appeared last month.

Single-controller System

The next step in the evolution of the "standard-plant" reactor-control system is shown in Fig. 10. A single instrument having proportional plus derivative response is used with its bulb located in the reactor. The instrument controls the steam and water inlet valves directly, rather than through a pneumatic-set controller.

The control valves were equipped with precisors (valve positioners) to obtain accurate positioning and staggered operating pressure sensitivities because the controller sensitivity was slightly lower than that with the pneumatic-set system.

As a result of the lower sensitivity requirement, there was a slight drift of the controlled temperature as the reaction progressed. This was not objectionable. Overpeaking on the rise to holding temperature was eliminated. Fig. 11 shows the results.

This control system was used successfully and could automatically take care of wide variations in charging. During the reaction the water temperature is changed over a considerable range—as much as 50 deg. F.—and the deviation from the desired control point is generally within 1 deg. F. This is because the stabilizing effect of the derivative action permits relatively high sensitivity settings to be used.

As the design of the standard copolymer plant progressed, many discussions of the reactor control system developed as the result of the pooling of information by design engineers of the four large rubber companies.

The outcome of months of deliberation resulted in the decision to use a controller with automatic reset because it was planned to charge the reactor within a few degrees of the operating temperature. It was argued that there would then be no problem of overpeaking, and compensation for load changes during the reaction would be effected by reset action. Hence, all the reactors were furnished with this type of instrumentation.

As the plants were put into operation it was found to be very difficult to control all ingredients so as to have the charge at operating temperature. Consequently, the reactor-temperature control was erratic; overpeaking and cycling of the temperature resulted.

Let us reappraise the features of the various control responses that are used on the reactor-control system: Pre-Act, or derivative response, is effective in eliminating overpeaking at the beginning; however, the control point drifts slightly with load changes if Pre-Act only is used. Automatic reset maintains the control point accurately but can not prevent overpeaking at the start. Automatic reset and Pre-Act in combination do not eliminate, but do reduce the overpeaking.

The "Standard Plant" Reactor Control System

As the result of the experience with the controller using automatic reset alone, and because of the fact that the reactors could not be accurately charged at the polymerization temperature, the controllers were changed to proportional plus derivative response in the field in 1943. The complete control system is shown in Fig. 12. Steam is shut off and cooling water is admitted to the jacket before the control point is reached. The point at which this takes place is a function of the sensitivity setting (proportional band); the amount of valve action is dependent on the Pre-Act time adjustment. A sensitivity of 20 psi./in., or a throttling range of about 14.5 percent, and a Pre-Act time of about 2 minutes gave good results, preventing overpeaking regardless of charging temperature and with minimum drift during the reaction. It might be mentioned again that there is no constant load condition during the reaction period. As a result, the temperature tends to rise or fall. With Pre-

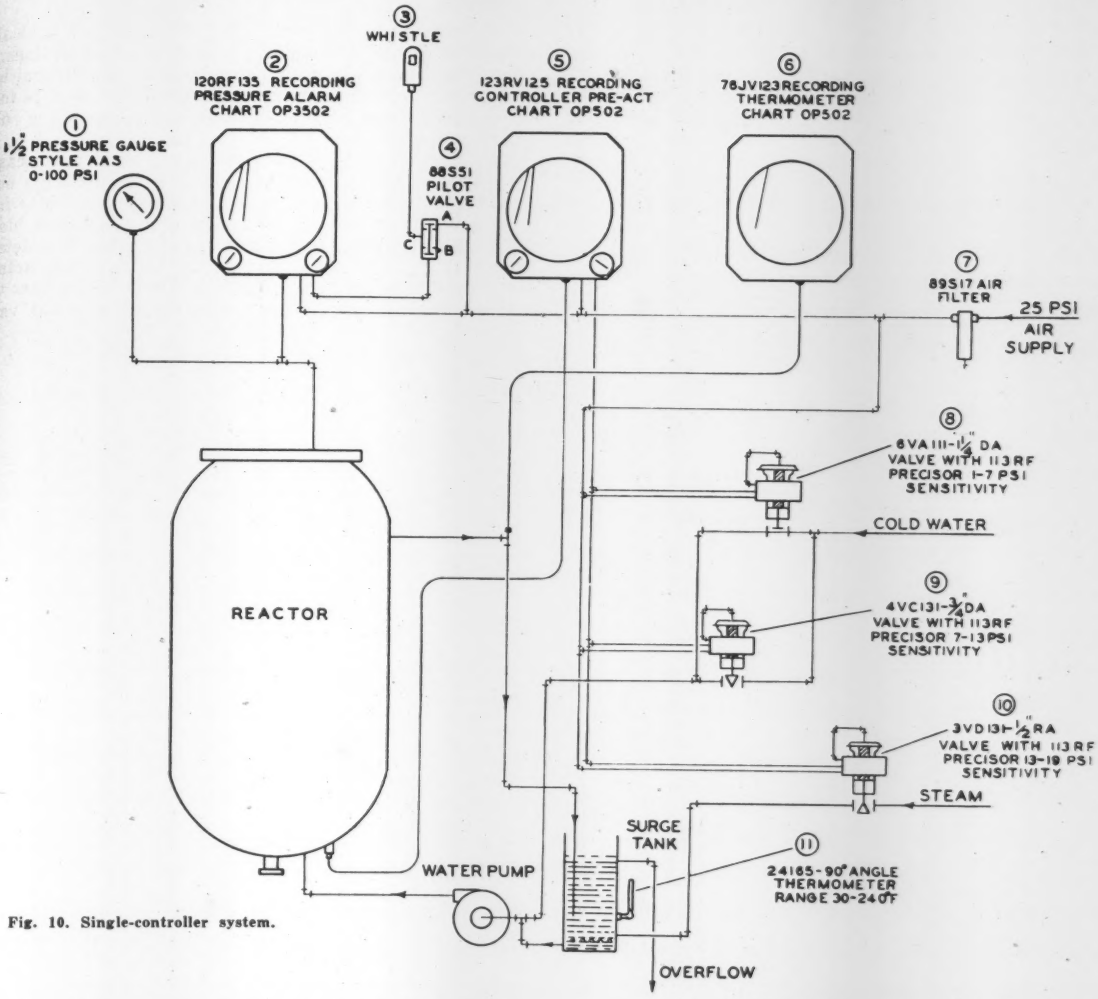


Fig. 10. Single-controller system.

Act, the deviation was less than with reset and was practically negligible for the entire reaction period.

E. E. Rowland in his paper "Control of Reactors for Synthetic Rubber" (*Instruments*, Vol. 20, Feb. 1947, page 136) discusses the single-instrument and double-instrument control. In his work in 1945 he obtained the most satisfactory operation with the 2-controller setup. The master controller was equipped with proportional, reset, and derivative responses; the pneumatic-set water-temperature control had proportional plus reset response. However, in order to prevent overpeaking, he set the pointer of the primary controller lower than the charging temperature for at least 2 hours before starting the batch. This was to allow the system to balance at zero pressure before elevating the pointer to the operating temperature. As the instrument was not completely reset to the higher output air pressure during the rise, the derivative mechanism became effective before the control point was reached. Therefore the water temperature could be changed over a wide band for a comparatively small change in temperature rise as the control point was approached. It will be recognized that this procedure required some manual attention.

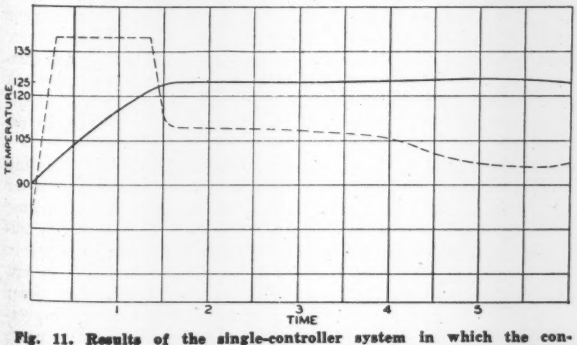


Fig. 11. Results of the single-controller system in which the controller has proportional and derivative action. Time scale is in hours.

At last year's symposium, R. E. Clarridge* presented "A New Concept in Automatic Control," which introduced a new pneumatic circuit. This circuit incorporates the three control effects in such a way that automatic reset can be used without overpeaking on start-up. This is accomplished by arranging the three responses into two separate circuits. The first half incorporates proportional plus derivative; the second half proportional plus automatic reset. As two proportional bands exist, this controller could be called a two-band controller, the first band being affected by the derivative response and the second being affected by the automatic-reset response.

The advantages of this system on the reactor control are indicated by the performance characteristics in Fig. 13.

Continuous Polymerization

Further development work in the synthetic rubber field resulted in continuous polymerization. The reactors are piped in series and the product is pumped slowly through the system. The ingredients flow to the first reactor, being controlled by flow controllers set at predetermined values to give the proper ratio of the raw materials. The reaction

* *Instruments*, Vol. 23, December 1950, page 1248.

continues as the product passes from one reactor to the next, each reactor temperature being controlled by the same type instrument as was used in the batch process.

Several displacement reactors, placed at the end of the chain, are cut in and out depending on the solids content of the product so as to lengthen or shorten the total reaction time.

A recording back-pressure controller maintains the pressure in the reactor system by controlling a Saunders-type valve on the latex discharge line.

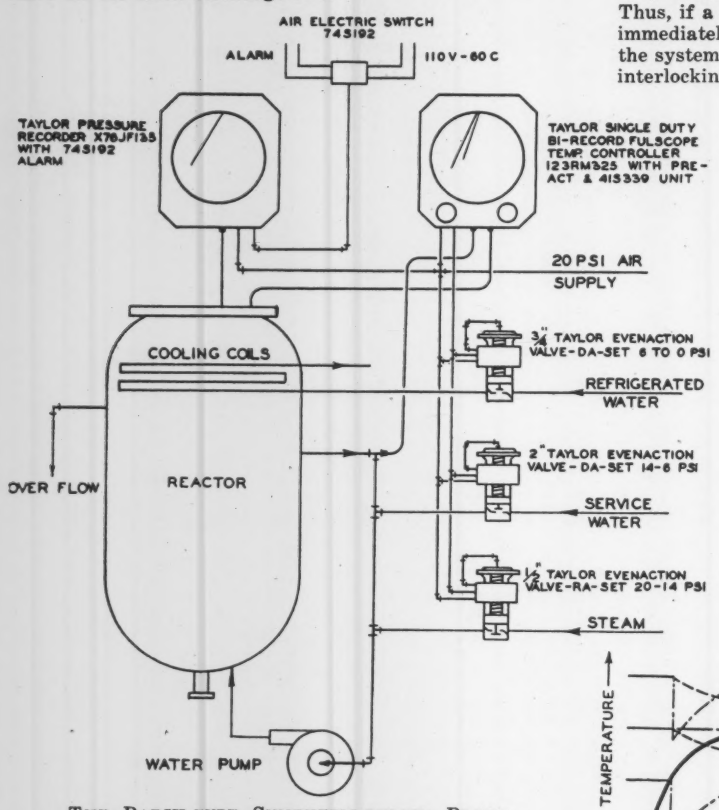


Fig. 12. The "standard plant" reactor control.

The Batch-type Synthetic-rubber Plant

Fig. 14, which is a schematic layout of a synthetic-rubber plant of the batch type, shows the main processing equipment.

From the reactor the contents pass to a receiver where an anti-oxident and a reaction stopper are added. The temperature is controlled at the receiver, and the free butadiene is liberated and recovered.

From the receiver, the latex solution passes through a stripper. The flow is controlled by glass-lined Saunders-type valves and glass-lined Venturi tubes. Steam pressure and rate of flow to the stripping column also are controlled by pressure and flow controllers. In the stripper, the free styrene is recovered, condensed, and sent to storage.

Next, the latex is pumped to coagulators where it is mixed with acid and brine to form crumbs. Flow of latex is controlled, again using Venturi tubes and Saunders-type glass-lined valves. The pH of the coagulants also is controlled by admitting the ingredients to the coagulators.

After coagulation, the crumbs are washed as they pass over continuous filter-washers.

The washed crumbs then pass through a continuous drier whose temperature is controlled accurately in zones by steam in coils. These driers are equipped with a multiplicity of motor-driven fans to insure adequate circulation.

Fire-control System.—A unique safety device is in use in one synthetic rubber plant for the control of fire in the drier. Although not adopted in the standard plants, the system provides for flooding the drier with steam in event a fire breaks out in any part of the drier.

As shown in Fig. 15, the drier system uses a typical atmospheric tunnel-type drier, divided into two sections, one above the other. Warm air, circulated by centrifugal blowers, enters the top part of the compartment and is forced downward across the heating coils and through the rubber to the lower suction.

The thermal systems for detecting a sudden increase in temperature, which might be caused by the breaking out of fire, are made up of four or five capillary-type bulbs in series. One bulb is placed in front of the intake to each blower. Thus, if a fire starts at any point in the drier, it is detected immediately. Excessive temperature at any bulb actuates the system. The output air from the controllers passes to an interlocking control system consisting of solenoid valves,

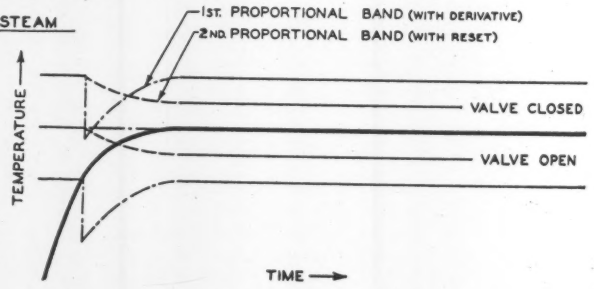


Fig. 13. Performance characteristics of a controller whose proportional band is affected by both derivative and reset action.

pilot valves, pressure switches, and relays—and thence to the steam valve.

While the drier is operating at its normal temperature, air is supplied by all fire-control systems, and the interlock system is in position to allow air pressure to close the valve in the steam-inlet line. The fan motors and the conveyor are running. If a fire breaks out and is detected by one of the bulbs, the temperature rises and the controller shuts off its output air. Regardless of which controller system operates, the interlock is so energized that the steam valve opens to flood the drier with steam, and the fan and conveyor motors stop. The steam cannot be shut off until the temperature in the drier returns to normal and the interlock is reversed by push button to apply air to the motor of the steam valve. The fans and the conveyor can then be restarted.

The final step in the synthetic-rubber process is the baling of the rubber crumbs as they are delivered by the drier (Fig. 14). This is accomplished in a hydraulic-operated press controller by a time-cycle controller. It is entirely automatic in operation. When the 75-lb. charge of rubber in the hopper is weighed, it trips a limit switch which dumps the charge into the baler and starts the timer. The timer then puts the cover on the baler, applies low hydraulic-pressure to the ram to compress the charge, bumps the press to remove air from the bale of rubber, applies high pressure

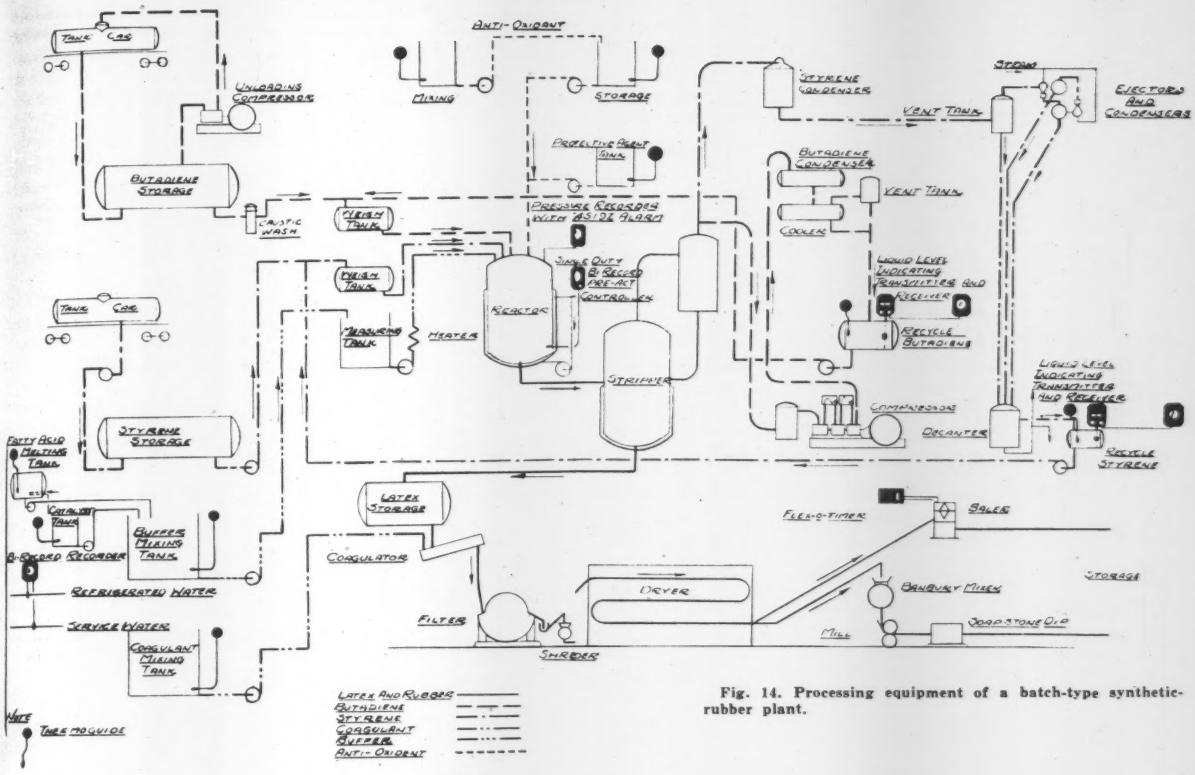


Fig. 14. Processing equipment of a batch-type synthetic-rubber plant.

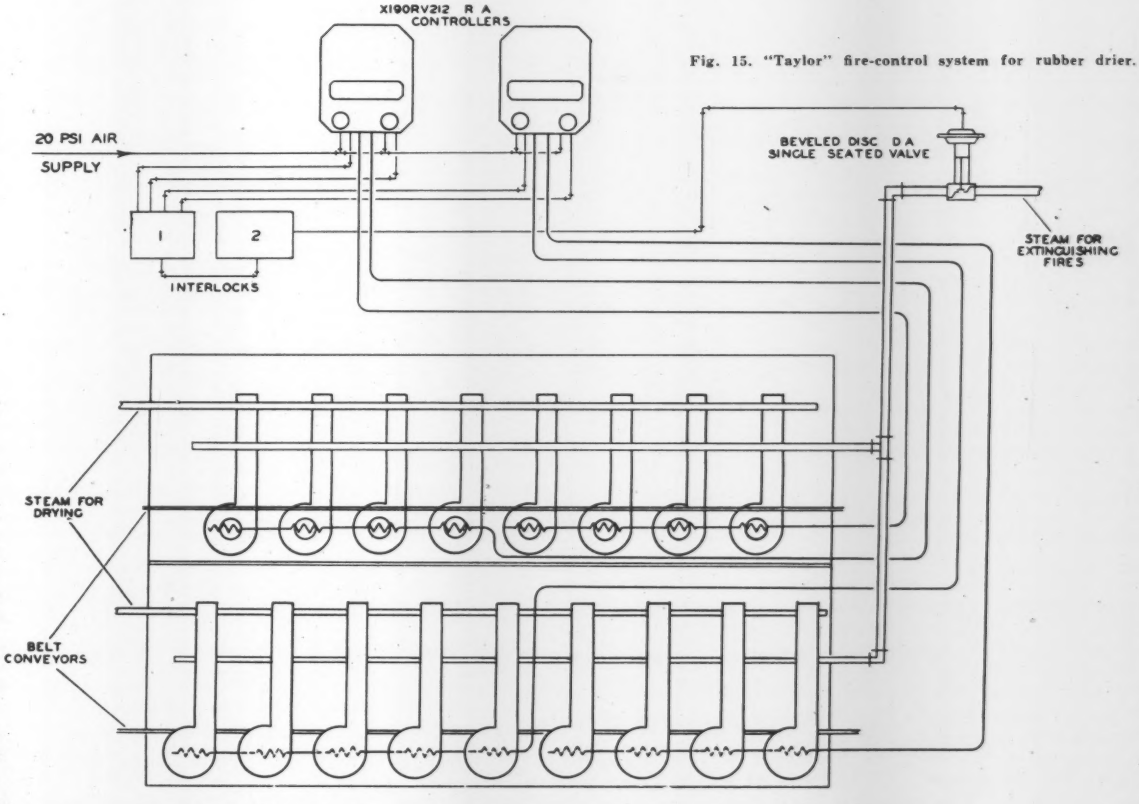
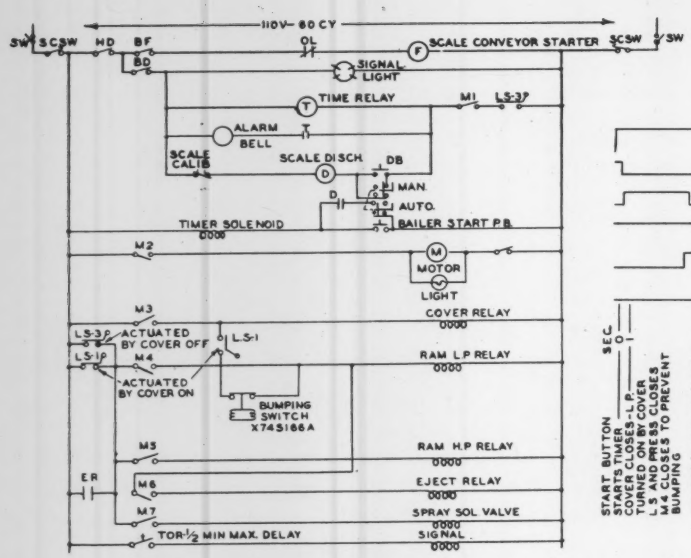


Fig. 15. "Taylor" fire-control system for rubber drier.

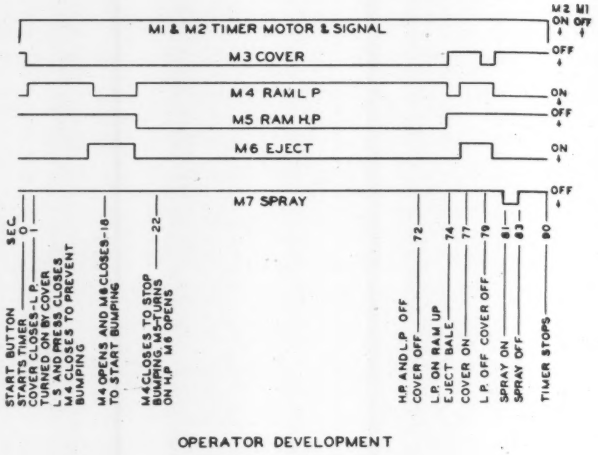
to the ram, compresses for a short period, then lowers the ram, removes cover, and ejects the bale of rubber. Fig. 16 shows the schematic diagram and the sequence of operations of this system.

Cold Rubber

A superior synthetic rubber, especially for tires, known as cold rubber, is now being made in some of the plants.



SCHEMATIC CIRCUIT DRAWING



OPERATOR DEVELOPMENT

Fig. 16. Schematic diagram and sequence of operations of "Taylor Flex-O-Timer" applied to a synthetic-rubber baling press.

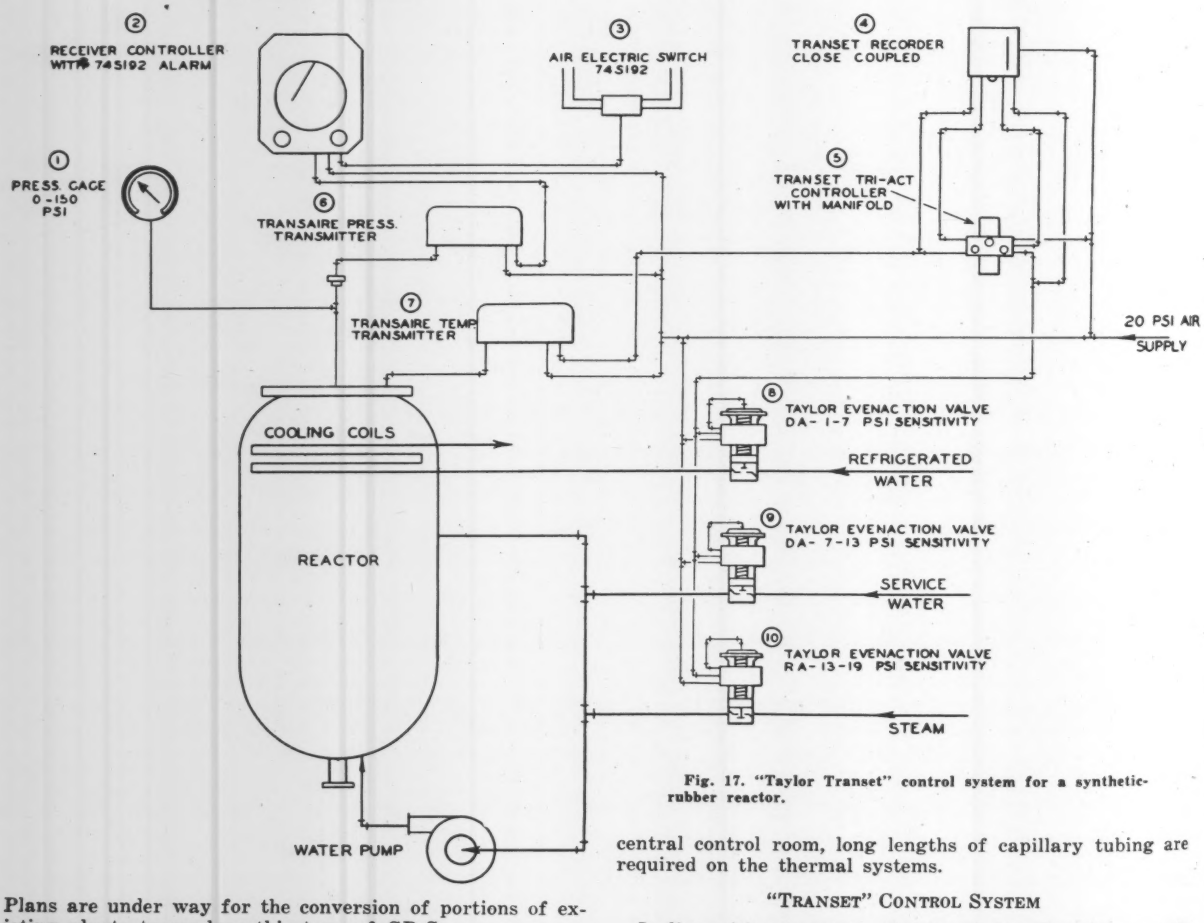

② RECEIVER CONTROLLER WITH 745192 ALARM
③ AIR ELECTRIC SWITCH 745192
④ TRANSET RECORDER CLOSE COUPLED
① PRESS. GAGE 0-150 PSI
⑤ TRANSET TRI-ACT CONTROLLER WITH MANIFOLD
⑥ TRANSAIRE PRESS. TRANSMITTER
⑦ TRANSAIRE TEMP. TRANSMITTER
20 PSI AIR SUPPLY
⑧ TAYLOR EVENACTION VALVE DA-1-7 PSI SENSITIVITY
COOLING COILS
REFRIGERATED WATER
⑨ TAYLOR EVENACTION VALVE DA-7-13 PSI SENSITIVITY
REACTOR
SERVICE WATER
⑩ TAYLOR EVENACTION VALVE RA-13-19 PSI SENSITIVITY
STEAM
WATER PUMP

Fig. 17. "Taylor Transet" control system for a synthetic-rubber reactor.

Plans are under way for the conversion of portions of existing plants to produce this type of GR-S.

The process is almost identical with the one described except that polymerization takes place at 41 deg. F. instead of 122 deg. F. The same-type instruments are used by changing the thermal systems to a lower range and by using a refrigerant instead of water in the jacket circulating system. The reaction time is considerably longer.

As the reactor temperature controllers are located in a central control room, long lengths of capillary tubing are required on the thermal systems.

"Transet" Control System

In line with present trends, the plants changing over to cold-rubber manufacture are giving consideration to the use of force-balance-type temperature transmitters, and converting the present controller to a receiver controller—or replacing it with the new controller having the improved circuit to eliminate overpeaking and yet compensate for load changes. The latest concept in the reactor system is shown in Fig. 17.

The adaptation of the new two-band controller to the present reactor control system is shown schematically in Fig. 18. To adjust this system, the sensitivity of the existing controller is set to produce a 3 to 15 psi. output pressure change for 100 percent pen travel with the set pointer at midscale of the chart.

The instrument is synchronized to produce a 9-psi. output when pen and pointer are together. The output of the precision reducing valve is set at exactly 9 psi.; this same reducing valve can be used to load any number of similar units.

Next, set the control index to the desired value on the chart. The Tri-Act controller controls and brings the process to equilibrium with a 9-psi. output from the original controller, which is the value obtained when set point and control point are coincident.

All adjustments for gain, reset, and derivative are made on the Tri-Act controller.

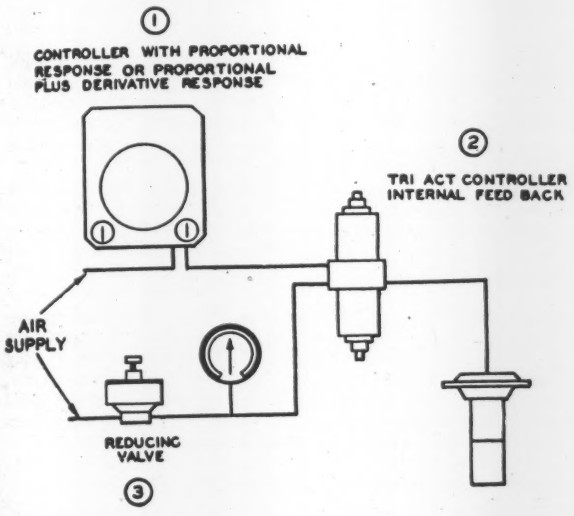


Fig. 18. Use of "Tri-Act" controller with existing "123R" controller to achieve "two-band" control.

ACKNOWLEDGEMENT

Acknowledgement is made of information obtained from "Synthetic Rubber, History and Importance Today," published by United States Rubber Company, February 1947.

DISCUSSION

R. L. Mallory: It is interesting to note control selected for the standard plant turned out to be exactly what you disposed of initially as being inadequate for the job. You might want to comment upon that in a few minutes. In the trial of the time-schedule control, I don't believe you mentioned what responses were used. You did mention that one of the objections was the fact that you had violent changes in water temperature, which had detrimental effects upon your equipment, and also some process disadvantages. Later on, in discussing pneumatic-set equipment, you mentioned one of the advantages was the ability to obtain wide changes in product temperature. Would you care to discuss these points?

Detwiler: The adoption of the type of controller which was abandoned originally was the result of the discussion among the representatives of the rubber companies, the design engineers, and all the instrument manufacturers. An automatic-reset controller was adopted because they had definitely decided to charge the reactor at the polymerization temperature. As that was never possible, we changed in the field to the rate-response type of instrument.

The time-schedule controller was applied in a very narrow throttling band. As a result, during the rise to temperature the jacket water temperature was successively high and low. It was the wide and sudden variations in the water jacket temperature that was objectionable. It is possible also to set or limit the jacket water temperature during the rise to temperature in order to overcome overpeaking, but that lengthens the reaction time. During the war we were interested in producing synthetic rubber as fast as possible. We were allowed to make that one change in temperature over a fairly wide limit, but that was after the reaction temperature had been reached, and it was not considered objectionable. It may have caused a slight buildup of film on the lining of the reactor, but it wasn't too bad.

Charlie Miller: In one of the original experimental systems we controlled from the jacket temperature during the first part of the cycle and then shifted automatically to the product temperature. How was that accomplished?

Detwiler: Two little pilot valves operated from the output air pressures from the control systems accomplished that shift. As the product temperature reached the control point, the output air pressure from that system actuated the pilot valve which then shifted the control to the other system.

Ralph Webb: How did the pressure change during the reaction?

Detwiler: The reactor pressure built up gradually as the temperature increased. When the reaction temperature was reached, the pressure leveled off. It did not rise unless there had been some mistake in charging the reactor, in which case a more violent reaction might have taken place to increase the pressure, in spite of the fact that the temperature was held down.

Webb: Did the pressure hold up during the entire reaction?

Detwiler: Yes. The reaction time was determined entirely by the solids content of the latex.

Russell Brant: I believe the reaction pressure did drop off as the jacket water temperature was decreased.

Detwiler: That may be so. I have not seen many charts since these plants have been reactivated.

Brown (Kentucky Rubber): As the pressure in the reactor is the vapor pressure of butadiene, the vapor pressure does drop off because the emulsion gets weaker as the reaction progresses.

Detwiler: I stand corrected.

Mallory: It appears to me that the laborious way that the problem was approached is no different from how the rest of us approach it. Is there a way that a problem like that can be attacked, based on experience with similar applications, mathematically or some other way, so as to eliminate a lot of the physical steps that we take in arriving at the best solution? Granted, the conclusion is a case for control form that didn't exist at the time that the experiments were being made, yet there undoubtedly was a good control solution to that application at the time. Whether you arrived at the best one or not is another matter, but we all do exactly the same thing. We start out—we grab a handful of equipment and attack a problem. I sometimes wonder if we don't do it without a thorough analysis to see if we can't determine in advance exactly what is best suited to the application. As an application engineer, Mr. Detwiler, you might want to make some comment on that.

Detwiler: I think the main problem was the time element. Most of the laboratory work on the temperature control system was done on production units. As soon as you worked out one control system, everything would change overnight and they would do things a different way the next day. We didn't have enough time to do it.

Webb: The expediency of the times and the pressure from Rubber Reserve and others justified any approach to the problem.

Mallory: Could a half-day's thought rather than a week's work have been more effective in coming up with the answer?

Detwiler: They didn't give you that much time and they wanted action and not pencil pushing; that was the result.

INSTRUMENTATION of OXYGEN PLANTS

To instrumentize a plant, it is necessary to know the performance characteristics of the process. This article describes the HRI oxygen plant, its characteristics, and its instrumentation.

By J. H. ARNOLD
Hydrocarbon Research, Inc.

TWO most important considerations in the design of an oxygen plant are capital cost and power cost. As the two are never entirely compatible, it is always necessary to compromise one or the other or both to achieve the most profitable operation. Instrumentation, being an integral part of the design of an oxygen plant, is subject to the same considerations. To afford some insight about the factors which affect the cost of oxygen, the present discussion of instrumentation is prefaced with an outline of the special design characteristics of oxygen plants in general, and with a brief description of the arrangement of equipment and operation of a particular plant, including the basic control system.

Special Design Characteristics of Oxygen Plants

The separation of oxygen from air is more simple than most industrial processes. If air could be liquefied at normal temperature, the separation would be as simple as super-atmospheric temperature-distillation processes such as the topping of gasoline from crude oil or the distillation of alcohol from mash. However, air at ordinary temperatures is a fixed gas, well above its critical temperature. Therefore, air must be liquefied at extremely low temperatures. The major problem is the high degree of conservation of refrigeration demanded by the economics of the process. More than 98 percent of the refrigeration requirement of the plant must be recovered from the cold products of distillation; otherwise, power costs become prohibitive.

A second complication is a requirement of the distillation. Not only must the air be liquefied but, in addition, a source of liquid nitrogen must be provided to effect the separation of the nitrogen from oxygen. In any fractional distillation it is necessary to have a certain minimum quantity of the lowest-boiling product—nitrogen in this case—in liquid form, flowing constantly into the top of the fractionating tower. The economics of the process demand that the liquefaction of nitrogen be achieved with high thermodynamic efficiency to avoid expenditure of unnecessary power.

A third complication is the requirement of a supplementary source of refrigeration. Theoretically there is sufficient refrigeration available from the cold products of distillation to satisfy the entire refrigeration load, but even the most efficient plants have small inefficiencies which must be offset by a supplementary source of low-temperature refrigeration. Again the economics of the process demand that this be accomplished with high thermodynamic efficiency.

A fourth complicating characteristic is the necessity to eliminate from the plant the small quantities of water, carbon dioxide, and acetylene which are contained in the air. Unless the water and carbon dioxide are eliminated continually they accumulate as solids in the exchangers and towers and rapidly interfere with the normal flow of liquids and gases. The accumulation of solid acetylene in the reboiler of the distillation column or elsewhere must be avoided because of its tendency to explode in the presence of liquid oxygen. The removal of these fouling compounds must be accomplished without seriously complicating the equipment or significantly increasing the power requirements or other direct operating costs.

Gaseous oxygen was first produced in tonnage quantities by the Linde Frankl process approximately twenty years ago. Since then commercial plants have been built embodying several other processes. All the processes liquefy air and effect the separation of oxygen by fractional distillation. They differ from one another chiefly in the power expended and the methods and equipment employed to conserve refrigeration, to provide nitrogen reflux, to supply the supplementary refrigeration, and to eliminate the fouling compounds. The instrumentation obviously must be accommodated to the particular process. However, the general problems of measurement and control of flow, pressure, temperature, etc., are common to all processes.

The HRI Oxygen-separation Process

The instrumentation of the Hydrocarbon Research, Inc., plant, which forms the principal subject matter of this article, is based on actual operating experience of three of the largest commercial units ever built and three small demonstration uits. The HRI process is illustrated by the simplified flow diagram of Fig. 1. The particular cycle shown is the basic design of a plant that produces relatively large quantities of tonnage oxygen—that is, 90-97 percent pure gaseous oxygen. Modifications of this cycle are available for smaller plants and for plants that produce simultaneously with tonnage oxygen, or in any desired combination, high-purity welding-grade or medicinal oxygen, liquid oxygen, oxygen-free nitrogen, argon, krypton, and xenon.

The HRI process (Fig. 1) is a relatively simple but highly integrated cycle. Atmospheric air is first filtered (1) to remove dust and fog, then compressed (2) to approximately 70 psig., cooled (3) in exchange with water, and freed of liquid water in a combination surge-drum and entrainment-separator (4). The cooled compressed air is refrigerated to minus 278 deg. F. in reversing exchangers (5) and (6), as it flows counter to the cold nitrogen and oxygen. All water vapor and essentially all carbon dioxide are precipitated in the reversing exchangers coincidental with the cooling of the air.

The refrigerated air enters the base of the high-pressure tower (7). There the bulk of the air is liquefied and fractionated at 67 psig. into two essentially equal parts—an overhead liquid termed "nitrogen reflux," and a bottom liquid termed "rich air." Between 20 and 25 percent of the air entering the high-pressure tower is washed by the liquid flowing over the lower trays of the tower. This removes the last traces of carbon dioxide and the acetylene. The air is withdrawn at essentially the same temperature as it enters the tower. This fraction of the air is then reheated to minus 245 deg. F. by passing a portion of it back through the cold end of the reversing exchanger (6) and mixing this

Presented at the A & M College of Texas' Sixth Symposium on "Instrumentation for the Process Industries," Houston, Tex., Sept. 10-14, 1951.

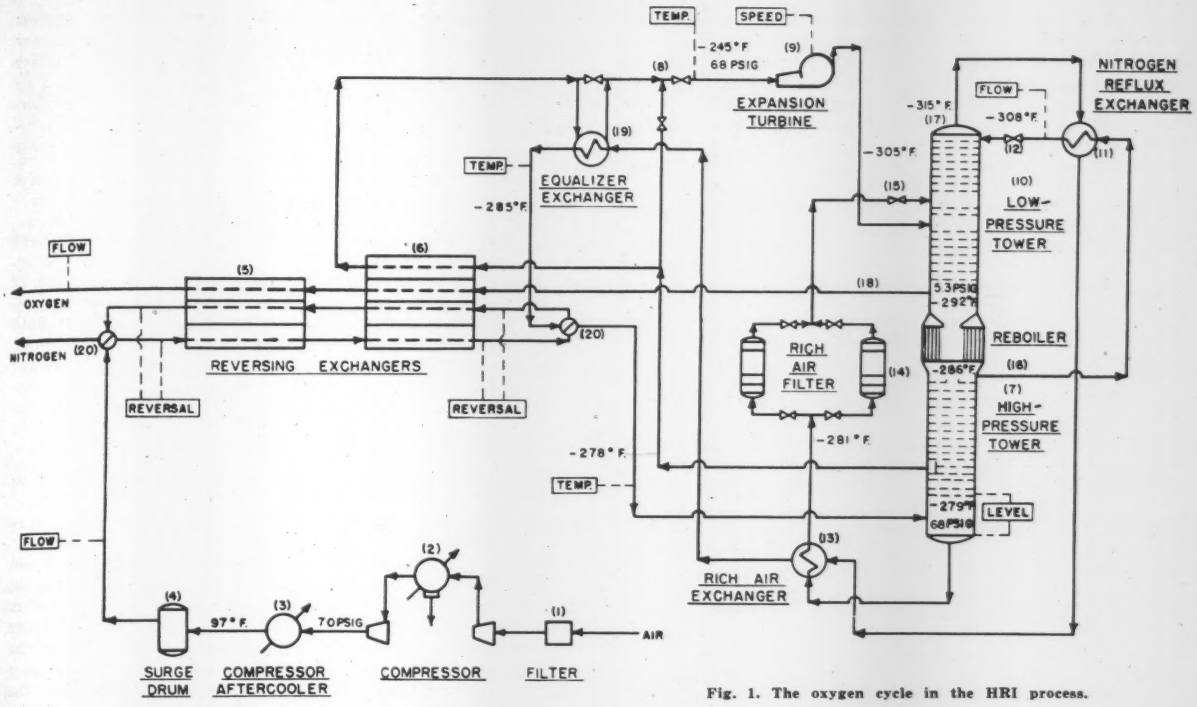


Fig. 1. The oxygen cycle in the HRI process.

portion with the remainder (8). The reheated air is expanded to approximately 5 psig. through a turbo-expander (9) to supply the supplementary refrigeration requirement of the system.

The expanded air, at minus 305 deg. F., enters the low-pressure tower (10) approximately midway between the top and bottom. The nitrogen reflux from the top of the high-pressure tower, free of all traces of fouling compounds, is subcooled to minus 308 deg. F. by exchange (11) with nitrogen product leaving the top of the low-pressure tower, and then expanded through a valve (12) into the top of the low-pressure tower. The rich air from the bottom of the high-pressure tower is subcooled to minus 281 deg. F. also by exchange (13) with the nitrogen product. It then is passed through a combination filter and absorber (14), which removes the last traces of carbon dioxide and the acetylene, and finally is expanded through a valve (15) into the low-pressure tower at approximately the same location as the expanded air.

Between the low-pressure and high-pressure towers is the reboiler condenser (16). The rising vapors in the high-pressure tower furnish heat to boil the liquid oxygen at minus 292 deg. F. in the base of the low-pressure tower. In furnishing this heat, the vapors are condensed at minus 286 deg. F. The gaseous nitrogen product (17) leaves the top of the low-pressure column at minus 315 deg. F.; the gaseous oxygen product (18) leaves the bottom of the same column just above the liquid level.

The oxygen product, free of carbon dioxide and water, flows at a steady rate directly from the low-pressure tower, through the reversing exchanger, to the suction of the oxygen compressor, or booster (not shown). The nitrogen product, after exchange with the reflux streams from the high-pressure tower, is further heated to minus 285 deg. F. by exchange (19) with a part of the reheated air. This reduces the temperature difference between the nitrogen and the air at the cold end of the reversing exchanger to approximately 7 deg. F. The tempered nitrogen product then flows counter to the air through the reversing exchanger to the atmosphere (if it is to be wasted), or to a pumping station (if it is to be further utilized). The nitrogen product leaves the reversing exchanger at essentially atmospheric pressure and about 4 deg. F. below the temperature of the air entering the reversing exchanger. Every 15 to 25 minutes the flow paths of nitrogen and air through the reversing exchangers are switched by operating the valves (20) at either end of the exchangers. Oxygen product flows continuously through separate passages uninterrupted by the reversal of flow of air and nitrogen. By reversing the flows of air and nitrogen the water and carbon dioxide previously deposited from the air are revaporized and carried out of the plant with the nitrogen product, thus avoiding the fouling which would otherwise occur.

Control of the HRI Plant

In order to operate the HRI plant at maximum efficiency it is necessary to control accurately certain flows and temperatures. However, in such an integrated cycle the danger of overcontrol is as great as the danger of undercontrol. There is some freedom of choice of controls. Hence the control system described is not the only possible system, but it is one which has proved stable and flexible in plant practice. The necessary controllers are indicated on Fig. 1. The objective of control is to produce oxygen at the desired rate and purity with the minimum expenditure of power.

Following the line of flow through the plant the controllers, which are indicated by small rectangular boxes, are (1) the rate of flow of air from the compressor, (2) the temperature of the air leaving the reversing exchanger, (3) the periodic reversal of flow through the reversing exchanger, (4) the temperature of the air entering the expander, (5) the speed of the expander, (6) the rate of flow of nitrogen reflux from the high-pressure tower to the low-pressure tower, (7) the liquid level in the bottom of the high-pressure tower, (8) the temperature of the nitrogen product entering the reversing exchanger, and (9) the rate of flow of oxygen from the plant. It might appear that better performance would be obtained if more controllers were used. For example, there is no pressure control, no direct control of the flow to the expander, etc. However, a careful examination of the integrated cycle shows that the equipment imposes certain controls on the operation; to add to the nine externally imposed controllers noted would lead to overcontrol, to loss of efficiency, or even to instability.

Rate of Air Flow From Compressors

The primary control of the plant is the rate of flow of air from the compressors. If more oxygen and/or higher-

purity oxygen is desired from a plant which is operating efficiently, the flow of air must be increased; conversely, if less oxygen or purity is desired, the air flow must be reduced to maintain peak efficiency. Fortunately the flow characteristics (exclusive of the compressor) of an efficient oxygen plant are similar to the flow characteristics of a critical-flow orifice—that is, the rate of flow depends primarily on the head pressure. The characteristics of a centrifugal compressor are such that both discharge pressure and flow are functions of speed—pressure increasing with speed at constant flow, and flow increasing with speed at constant pressure. The combination of compressor and plant constitutes a stable system in which compressor speed determines rate of flow of air. This system is illustrated by Fig. 2 for a plant with a nominal compressor speed of 5000 rpm. and a nominal oxygen capacity of about 600 tons per day.

The characteristics of both compressor and plant are shown in Fig. 2 as functions of pressure and rate of flow. As the compressor speed is increased, the head pressure and rate of flow increase along the plant operating curve. Thus the flow of air to the plant can be controlled accurately by governing the speed of the compressor. In practice the compressor characteristics change with atmospheric conditions, and the plant characteristics change with variations in set points of the other controllers. However, in a well-operated plant these changes are neither great nor rapid. Thus manual adjustment of the compressor-speed set point is adequate. The speed of the compressor can be controlled in a number of ways, depending on the type of drive. One method, which has proved satisfactory in full-scale plants for both gas-engine and steam-turbine drives, is a manually set mechanical-governor with two servomotors in series—one to amplify the power of the governor, the other to control the valves regulating the flow of gas to the engine or the flow of steam to the turbine.

A second important variable of the oxygen plant is the discharge pressure of the compressor. As stated previously, this is an intrinsic control which is set by the flow characteristics of the plant. The primary control of the pressure in the high-pressure section of the plant is the reboiler condenser of the fractionating column, which acts much as the condenser on a steam engine. The condensing pressure is a function of the temperature of the coolant (the distilling liquid oxygen in the reboiler section), the amount of surface covered by coolant, and the coefficient of heat transfer from coolant to condensing nitrogen reflux. The temperature and hence the pressure of the high-pressure tower assume values consistent with the condensation of the quantity of air required by the particular flow rate—that is, the temperature of the condensing nitrogen reflux assumes the value necessary to give the required heat transfer across the reboiler, and the pressure assumes the value necessary to condense the nitrogen reflux at that temperature. Neither the temperature nor the level of the distilling oxygen is an independent variable. Therefore, whereas the conditions of the reboiler condenser set the pressure in the high-pressure system, the conditions in turn are dependent on other operating characteristics of the plant.

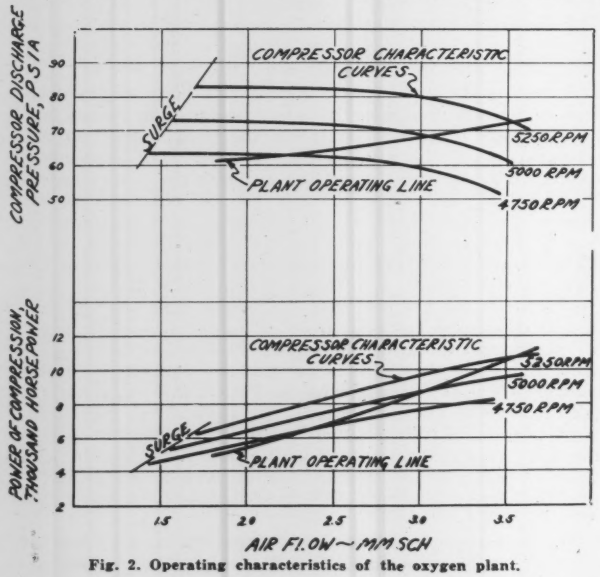


Fig. 2. Operating characteristics of the oxygen plant.

Temperature of Distilling Oxygen

The temperature of the distilling oxygen is dependent chiefly on the distillation pressure and, to a minor degree, on composition. The distillation pressure is set in turn by the pressure drop across the trays of the low-pressure column, plus the pressure drop of the nitrogen product path from the top of the low-pressure tower to the atmosphere. The pressure drop across the tower is reasonably constant; the pressure drop across the nitrogen path is a direct function of the rate of flow of nitrogen product. Hence the distillation pressure and temperature are set essentially by the nitrogen product flow, which in turn is set by the air flow. No external control is required, nor can it be applied without loss of efficiency.

Level of Distilling Oxygen

The level of the distilling oxygen in the reboiler is set by the supplementary refrigeration requirement of the plant and by the capacity of the expander. The expander is in essence a reaction turbine and has the flow characteristics of a critical-flow orifice. The mass flow depends only on the temperature and pressure of the air entering the expander and, as the inlet temperature is essentially constant, the flow depends almost wholly on the pressure. A certain combination of flow and pressure is necessary to balance the refrigeration requirement. However, in event of a transient deficiency of refrigeration, an excess of liquid in the reboiler is vaporized to compensate for the deficiency and consequently the liquid level falls. A decrease in reboiler level automatically raises the pressure in the high-pressure tower, as described previously. This higher pressure is reflected in all parts of the high-pressure system (including the inlet to the expander), more air is expanded, and the plant automatically approaches a new point of balance.

Inlet Air Temperature

The temperature of the air entering the expander is controlled so that the discharged air is approximately 2 deg. F. above its dew point. The inlet temperature is controlled by manually adjusting the valves which set the fractions of the air to be expanded and to flow through the cold end of the reversing exchanger, through the equalizing exchanger, and directly from the tower to the expander. A copper-constantan couple connected to a recorder is used to measure temperature; and manually-set pneumatically-operated butterfly-type valves are used for regulation of the flows.

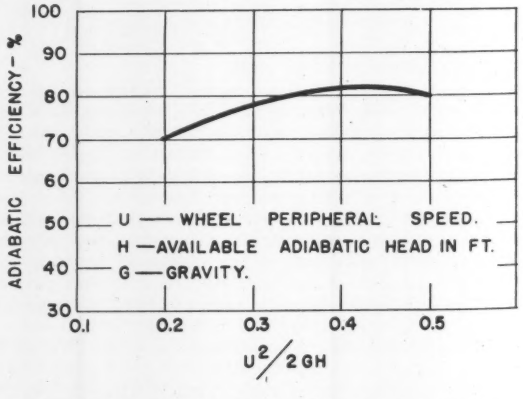


Fig. 3. Swearingen[1] curve of expander efficiency versus expander speed.

Expander Speed

The speed of the expander is controlled by controlling the speed of its brake—that is, the unit employed to absorb the power output of the expander. A proved brake for the expander is a centrifugal compressor which takes air at atmospheric pressure and discharges it into the intercooler of the main air compressor. A brake compressor and expander with correlated operating characteristics are chosen. The units are direct coupled. The speed is controlled by throttling the compressor output; increasing the degree of throttling increases the speed. Within relatively wide limits the thermodynamic efficiency of an expander changes only slightly with speed, as shown in Fig. 3. The combination of a conventional manually-set air-operated valve (for throttling the brake compressor) and a tachometer-generator coupled to the bearing oil pump shaft (with indicating potentiometer calibrated in rpm.) is performing adequately for this service in large plants.

Flow and Level of Nitrogen Reflux

Two other important variables which require external control are (1) the rate of flow of nitrogen reflux from the top, and (2) the liquid level at the bottom of the high-pressure tower. Physically, the nitrogen reflux stream can be varied from zero to the equivalent of all the air liquefied in the high-pressure tower. Practically, it must be controlled within reasonably narrow limits. A volume of liquid nitrogen reflux of high purity equivalent to at least 40 percent of the total air flow is required to separate the nitrogen and oxygen in the low-pressure tower. Also, a constant flow is necessary for efficient separation in both the high-pressure and low-pressure towers. Adequate control has been obtained in full-scale operation with double-seated air-operated valves set manually, and also set automatically by an orifice-flow controller.

Measurement of the absolute value of the flow has not been consistently reliable, probably because of the failure of the system to maintain balanced static heads in the high- and low-pressure taps of the orifice meter. However, adequate control has been achieved using empirically determined set points which lead to the desired separations in the two towers. A modification of current practice which has been designed to overcome present difficulties is shown in Fig. 4. The arrangement of elements is the same as for similar service at higher temperatures. The novel feature lies in the manner in which the static heads in the two taps remain equal. It is a characteristic of the system that there be two phases in the pressure leads—a liquid phase in the cold section, and a gas phase in the warm section. The contribution of the liquid phase to the static head *must* be essentially equal in the two leads. This is accomplished by confining the liquid to the essentially horizontal runs of the leads, and by restricting the insulation of the vertical sections to assure only gas phase at these locations. A slight change in position of the interface then has little effect on the overall static head.

Flow of Rich Air

The rate of flow of rich air from the bottom of the high-pressure column is simply the difference between the total liquefied air and the nitrogen reflux. A steady flow of this stream is achieved by controlling the level in the bottom of the high-pressure tower. This is accomplished in full-scale plants with displacement-type controllers. The installation of the displacement meter is shown in Fig. 5. The successful operation of the system depends on proper insulation of vessel and control element. If the heat leak into the system is low enough to obviate undue boiling of the liquid, there is no significant difference between this application and higher-temperature applications.

Temperature of Air From Reversing Exchanger

The temperatures of the air leaving the reversing exchanger and of the nitrogen entering the reversing exchangers are set in a manner which does not lend itself to simple explanation. The air temperature depends on the amount of heat transfer which occurs in the reversing exchangers. This heat transfer is the sum of (1) the heat transfer to the air being reheated prior to expansion and (2) the heat transfer to the nitrogen product. Thus there is any number of combinations of these two heat-transfer quantities which produces the correct air temperature.

The temperature of the nitrogen entering the reversing exchanger is set by the amount of heat transferred to it as it flows through the nitrogen reflux, the rich air, and the equalizer exchangers. It is beyond the scope of this article to trace the sequential motions required to bring about the desired control. It suffices to state that the control is simple enough to become intuitive with the operator. When equipped with exchangers of proper size having variable flow bypasses controlled by manually set valves, the plant has an intrinsic stability and flexibility which make instruments of fast response unnecessary. Temperature measurement by thermocouples is adequate for all valve adjustments. Manually-set pneumatically-operated valves have proved satisfactory for splitting flows.

Flow of Oxygen From Plant

The control of the flow of oxygen from the plant can be accomplished by any of a number of flow instruments. However, as it is generally necessary to compress the oxygen for subsequent use, speed control of the oxygen compressor is a convenient and satisfactory method of control. It has proved reliable in large plants.

Flow Reversal

The flow through the reversing exchangers is reversed by pneumatically operated valves on the warm end of the exchanger and by check valves on the cold end. Both single-seated bevelled-disc and rotary-plug-type valves have been used successfully on the warm end, and lift- and swing-type check valves on the cold end. All valve actions are automatic in accordance with a predetermined time cycle. A typical arrangement for timer and valves is shown in Fig.

Continued on page 352

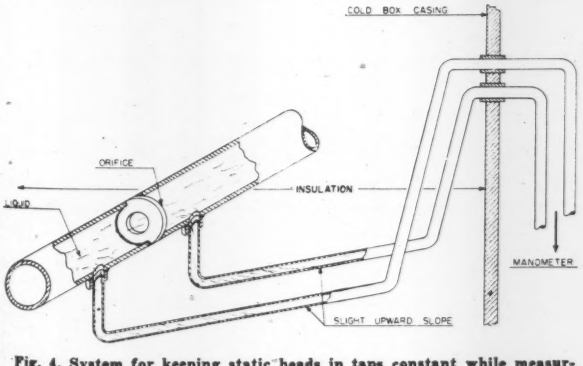


Fig. 4. System for keeping static heads in taps constant while measuring flow.

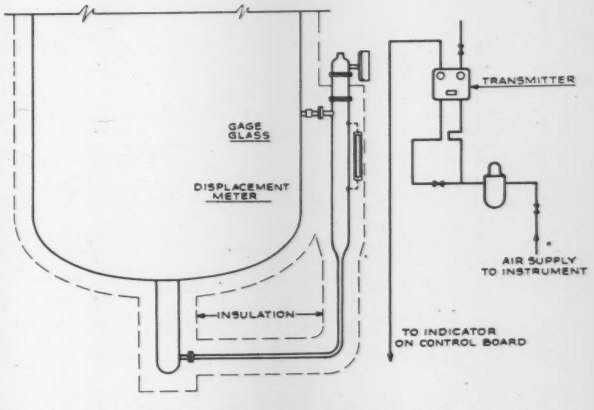


Fig. 5. Low-temperature level control.

OPTIMALIZING SYSTEM for PROCESS CONTROL

By Y. T. LI
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Editor's Note: This is the third and final installment of Mr. Li's article.

RESPONSE DELAY OF A PEAK-HOLDING SYSTEM (*Continued*)

The performance of the input linear group of an ideal system is similar to that of the output linear group. In general, the complete analysis of the operation of systems with both input and output linear groups may be preceded with an assumed input-output deviation difference at the instant of input reversal drive. The output and input linear group effects are introduced in turn around the chain of the optimalizing system. In general, after making the analysis around the chain of the optimalizing system for one complete cycle, it may be found that the final value of the input-output deviation difference is different from the value assumed at the beginning of the analysis. A new value of the input-output difference is then assumed to start another analysis cycle. By using continuous cut-and-try methods, the operation characteristics of the optimalizing system may be obtained, as shown in Fig. 16. In this figure the analysis was carried out under the assumption that both the output linear group and the input linear group of the optimalizing system have one first-order system.

In Fig. 16a the convertor output is represented by a light, solid-line curve; the smoothed output is represented by a heavy, solid-line curve. The smoothed output signal is identical with the output from the output linear group, as shown in Fig. 14.

Fig. 16 shows the indicated output-deviation signal, which is produced from the smoothed output signal. The intersection point of the output-deviation signal and the stabilization zone determines the reversal point of the drive signal, which is represented by the vertical dash line.

Fig. 16c shows the drive signal for the input-adjustor drive, which is supplied from a constant source with reversals controlled by input correction signal without delay.

The dashed line in Fig. 16d represents the integration of the drive signal to the input-adjustor drive under ideal conditions without time delay. This integration is performed by the input-adjustor drive in Fig. 14. The heavy, solid line of Fig. 16d represents the input signal with response delay caused by the first-order input linear group. The "round-off" of the heavy solid line from its asymptotes (the heavy dashed lines) is due to the exponential function introduced by the initial deviation difference, as explained previously.

Fig. 16a shows that the smoothed output signal between the indicated optimum point and the instant of input-drive reversal has approximately the same shape as the parabolic section of the input-convertor output. This means that in an ideal optimalizing system with the same stabilization zone setting as that shown in Fig. 16b, the input reversal occurs at a time interval equal to the *indicated input drive reversal time*, shown in Fig. 16 after the indicated optimum point. The corresponding output hunting period is equal to twice the indicated input drive reversal time, taking into account the symmetry of the parabolic function.

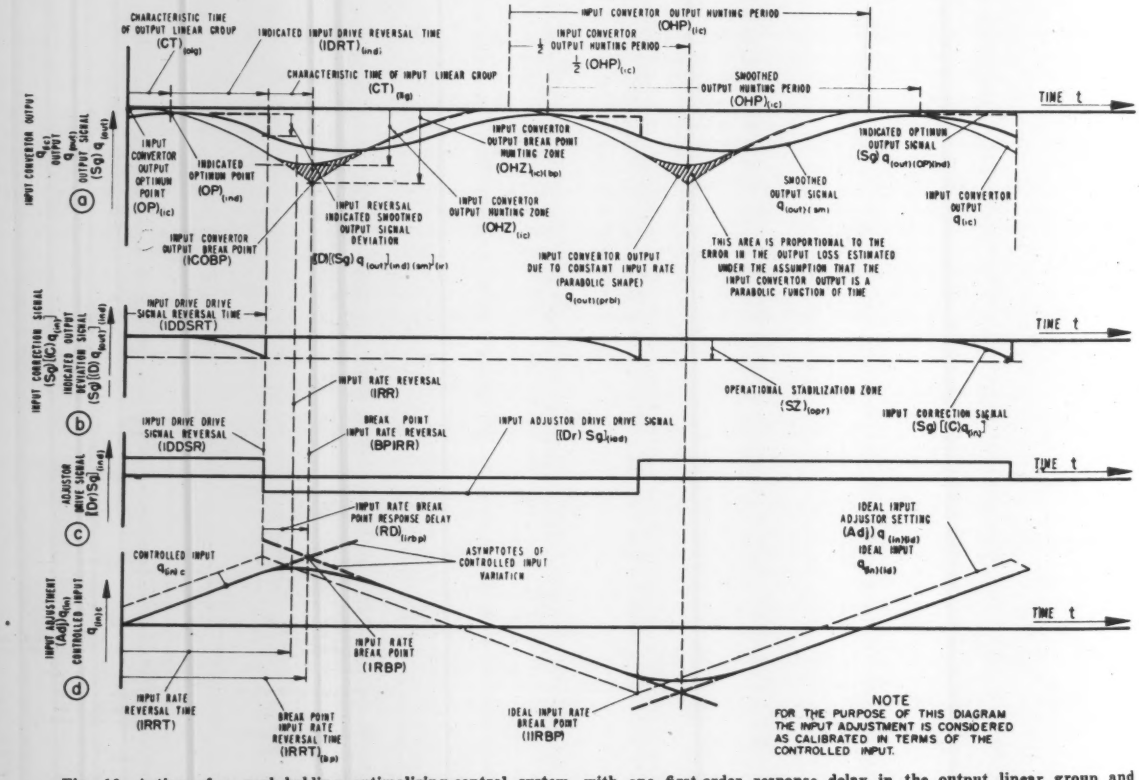

Fig. 16. Action of a peak-holding optimalizing-control system with one first-order response delay in the output linear group and one first-order response delay in the input linear group.

Fig. 16d shows that the actual input-rate reversal is represented by the peak of the heavy, solid-line curve. However, it is approximately true to consider the input-rate break point, which is the intersection point of the asymptotes of the controlled-input variation, as the input-rate reversal. The time between the true optimum point and the input-rate break point is called the *break-point input-rate reversal time*. In (a) and (d) of Fig. 16 it is shown that the break-point input-rate reversal time is equal to the indicated drive-reversal time plus the summation of the characteristic times of the linear groups. The corresponding output hunting period is equal to twice the break-point input-rate reversal time, taking into consideration the symmetrical effect of the asymptotes of the input rate.

From the preceding discussion it follows that, with everything else maintained equal, the introduction of first-order systems into an optimalizing system increases the output hunting period by a time interval corresponding to twice the sum of the characteristic times of the first-order systems. For a system with a certain constant input rate (in the case of air flow this is equivalent to rate of change of flow) the elongation of the output hunting period causes a proportional increase in the input hunting zone, which in turn causes an increase in the output hunting zone proportional to the square of the input hunting zone, or the input hunting period. The increase in the output hunting zone increases the output hunting loss, which is the main objection to the response delay introduced by the first-order linear groups.

In addition to the increase in the output hunting zone, the response delay effect of the linear group also sets a limitation on the operation speed of the control system. This is because the speed of the input-adjustor drive is determined from a certain input rate that would produce a suitable output hunting period considerably longer than the response delay. For a long hunting period, a low input-drive speed is needed, which in turn slows down the recovery time.

There are certain types of operating systems which have some linear systems with excessively long response delays. If the controlled system operates with a rather fast drifting rate, which requires fast recovery time, the designer has no suitable input rate to use. He may have to improve some of the response delay effects of the operating system, or else choose a control-system loop which bypasses those components with long response delays. For example, in the internal-combustion engine discussed in connection with Fig. 14, there is a response delay in the output coupler which corresponds to the piston-shaft mechanical system. This system can be bypassed in an optimalizing system by using a receiver connected to the input convertor to produce a signal representing the indicated power of the cylinder gas. With this arrangement the control system chain does not include the output coupler, so that the response delay of the output coupler is no longer an important factor in the operation of this optimalizing system.

Hunting Zone of a Peak-Holding Optimalizing-Controller

In the discussion of Fig. 9, the output hunting zone is defined as the range of output variation caused by input test-variations in the vicinity of the optimum level. Clearly, any output deviation from the optimum level is essentially an output loss. For satisfactory operation it is always desired to limit the output hunting zone to a small value.

The performance diagrams of Figs. 9 and 13 show that the existence of an output hunting zone depends largely on the setting of the stabilization zone, which determines the instant of reversal. Theoretically, for a smooth output signal like that shown in Fig. 9 or 13, the stabilization zone can be set infinitesimally small. Under this assumption, the corresponding output hunting zone is also infinitesimal.

In general, a stabilization zone is used primarily to prevent undesirable effects caused by interferences. An example of the relation between interference and stabilization zone is illustrated in Fig. 17. The upper plot shows the system output. The output includes a no-interference output (represented by the dash-dot line) and a periodic interference component with a fundamental frequency considerably higher than the hunting frequency (which determines the shape of the no-interference curve).

The lower plot of Fig. 17 shows the output deviation signal, which is used as the input correction signal. In this plot, discontinuous ripple signals due to interference are shown to the left of the optimum point.

Critical Stabilization Zone

If any ripple signals exceed the stabilization-zone limit, then an input rate reversal would occur because of the ac-

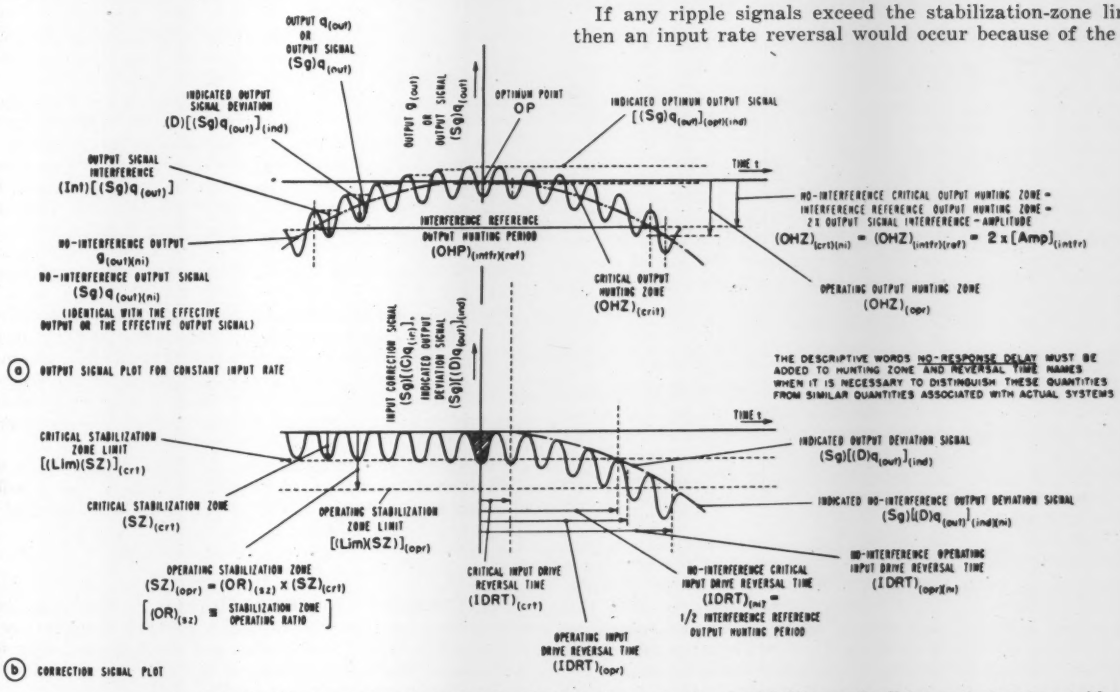
OUTPUT $q_{(out)}$ OR OUTPUT SIGNAL $(Sg)q_{(out)}$
INDICATED OUTPUT SIGNAL DEVIATION $(D)[(Sg)q_{(out)}]_{(ind)}$
OUTPUT SIGNAL INTERFERENCE $(Int)[(Sg)q_{(out)}]$
OPTIMUM POINT OP
INDICATED OPTIMUM OUTPUT SIGNAL $[(Sg)q_{(out)}]_{(opt)(ind)}$
TIME t
NO-INTERFERENCE CRITICAL OUTPUT HUNTING ZONE = INTERFERENCE REFERENCE OUTPUT HUNTING ZONE = 2 x OUTPUT SIGNAL INTERFERENCE - AMPLITUDE
$(OHZ)_{(crt)(ni)} = (OHZ)_{(intfr)(ref)} = 2 \times [Amp]_{(intfr)}$
INTERFERENCE REFERENCE OUTPUT HUNTING PERIOD $(OHP)_{(intfr)(ref)}$
NO-INTERFERENCE OUTPUT $q_{(out)(ni)}$
NO-INTERFERENCE OUTPUT SIGNAL $(Sg)q_{(out)(ni)}$
(IDENTICAL WITH THE EFFECTIVE OUTPUT OR THE EFFECTIVE OUTPUT SIGNAL)
CRITICAL OUTPUT HUNTING ZONE $(OHZ)_{(crit)}$
OPERATING OUTPUT HUNTING ZONE $(OHZ)_{(opr)}$
(a) OUTPUT SIGNAL PLOT FOR CONSTANT INPUT RATE
THE DESCRIPTIVE WORDS NO-RESPONSE DELAY MUST BE ADDED TO HUNTING ZONE AND REVERSAL TIME NAMES WHEN IT IS NECESSARY TO DISTINGUISH THESE QUANTITIES FROM SIMILAR QUANTITIES ASSOCIATED WITH ACTUAL SYSTEMS
INPUT CORRECTION SIGNAL $(Sg)[(C)q_{(in)}]$, INDICATED OUTPUT DEVIATION SIGNAL $(Sg)[(D)q_{(out)}]_{(ind)}$
TIME t
CRITICAL STABILIZATION ZONE LIMIT $[(Lim)(SZ)]_{(crt)}$
INDICATED OUTPUT DEVIATION SIGNAL $(Sg)[(D)q_{(out)}]_{(ind)}$
CRITICAL STABILIZATION ZONE $(SZ)_{(crt)}$
OPERATING STABILIZATION ZONE LIMIT $[(Lim)(SZ)]_{(opr)}$
INDICATED NO-INTERFERENCE OUTPUT DEVIATION SIGNAL $(Sg)[(D)q_{(out)}]_{(ind)(ni)}$
OPERATING STABILIZATION ZONE $(SZ)_{(opr)} = (OR)_{(sz)} \times (SZ)_{(crt)}$
$[(OR)_{(sz)} \equiv$ STABILIZATION ZONE OPERATING RATIO$]$
CRITICAL INPUT DRIVE REVERSAL TIME $(IDRT)_{(crt)}$
NO-INTERFERENCE CRITICAL INPUT DRIVE REVERSAL TIME $(IDRT)_{(ni)} =$ 1/2 INTERFERENCE REFERENCE OUTPUT HUNTING PERIOD
NO-INTERFERENCE OPERATING INPUT DRIVE REVERSAL TIME $(IDRT)_{(opr)(ni)}$
OPERATING INPUT DRIVE REVERSAL TIME $(IDRT)_{(opr)}$
(b) CORRECTION SIGNAL PLOT

Fig. 17. Effect of a periodic interference in the indicated output hunting zone of a peak-holding optimalizing control system (with no response delay) when the indicated output deviation signal is used as the input correction signal.

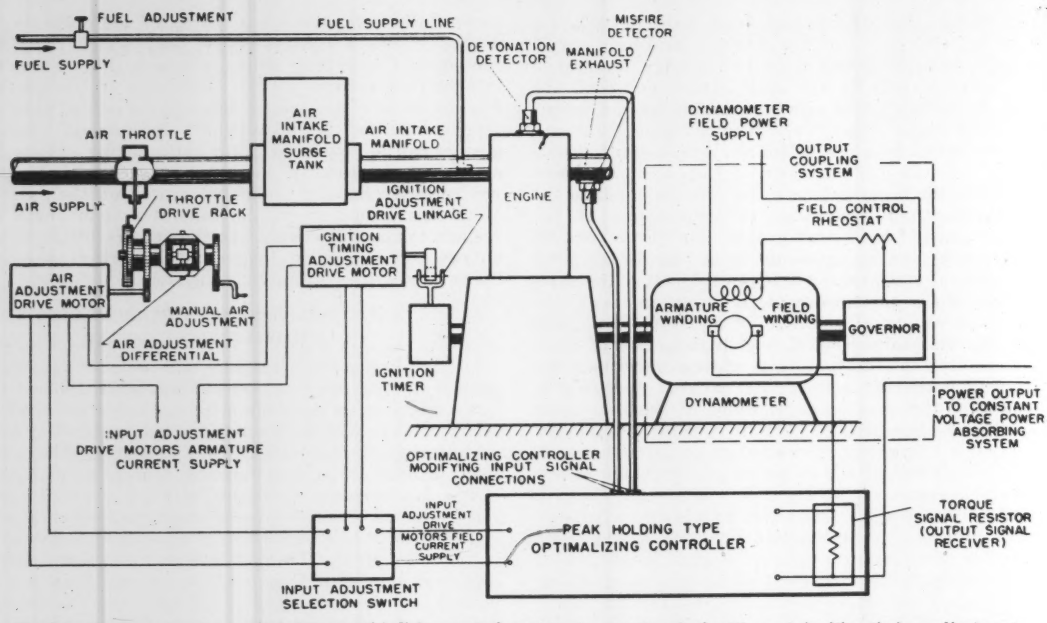

Fig. 18. Components of a peak-holding optimalizing-control system to operate air-throttle and ignition-timing adjustments.

tion of the peak-holding controller. In this situation the output would start to decrease before the actual optimum level is reached. To prevent this from happening, it is necessary to set the stabilization zone lower than a *critical stabilization zone*, which is defined as the stabilization zone barely sufficient to prevent an input rate reversal due to interference effects alone.

In Fig. 17b the stabilization zone actually used in operation is called the operating stabilization zone. The ratio between this stabilization zone and the critical stabilization zone is called the stabilization-zone operating ratio.

The input-drive reversal time and the output hunting zone resulting from the use of a critical stabilization zone or an operating stabilization zone are shown at the right-hand side of Fig. 17.

In general, the output hunting zone of a system is of the same order of magnitude as the interferences of the output signal used to generate the indicated optimum output level. The detailed relation between the interference and the output hunting zone is beyond the scope of this article. However, the discussion of Fig. 17 shows that in order to reduce the output hunting zone it is necessary to reduce the interference by use of a filter.

In the discussion of Fig. 14, the complete output linear group of the optimalizing system is actually a filter for the output signal. The signal that comes from the output linear group is called the smoothed output signal because a large portion of interference has been removed from this signal.

The smoothing effect of a first-order system on a high-frequency sinoidal function is shown in Fig. 15, J. With a single first-order system, the amplitude reduction of the high-frequency sinoidal function is approximately proportional to the ratio of the characteristic time to the period of the sine signal. This means that a first-order system with long characteristic time has more smoothing effect. However, a long characteristic time is always associated with a long response delay, which is the price paid for the smoothing effect.

When two first-order systems are used in series, the total amplitude reduction is equal to the product of the amplitude reduction of each stage, but the total response delay is only the summation of the characteristic times. For this reason an output linear group consisting of several stages of first-order systems connected in series is usually more desirable than a single-stage first-order system filter.

In an actual system the linear systems associated with the output coupler of the controlled system usually provide some smoothing effect, but it is usually not enough for satisfactory optimalizing-control action. For this reason, a signal-smoothing system is used in the controller to match the linear systems of the controlled system to give the desired smoothing effect.

Experimental Peak-holding Optimalizing-controller for a Reciprocating Internal-combustion Engine

In general, when an operating system is to be controlled with an optimalizing system there must be an optimum point on the performance characteristic curve of the operating system. Furthermore, an optimalizing system is particularly useful when the operating system varies in a complicated manner with the inputs, resulting in random output drift. The performance of an internal-combustion engine meets these two conditions and was therefore chosen for the experimental test.

The discussion of Fig. 9 shows that a recovery time is essential to overcome the drift of the operating system. The output hunting loss should be kept as small as possible. Therefore, fast recovery time and small output hunting loss are the two goals of an optimalizing-control system. In the experimental optimalizing-control system these goals were set to include an output hunting loss not exceeding 1/10 percent of the full power output of the engine, and a recovery time of 1/2 minute for a 5-percent initial output deviation.

Fig. 18 shows a peak-holding optimalizing-control system for a single-cylinder engine. This arrangement includes an input-adjustment selection switch, which alternately shifts the control action from one input to the other for selected time intervals. This action allows adjustment of both air flow and ignition timing to find the optimum engine performance as shown in Fig. 3.

The power-absorbing system of Fig. 18 includes a dynamometer and a speed governor, indicating the possibility of using a performance-regulating system in parallel with the optimalizing system.

Circuit Diagram

Fig. 19 shows the circuit diagram of the peak-holding controller. In this diagram the several circuits are surrounded by dashed-line blocks and labeled according to the individual functions corresponding to the components shown in the functional diagram of Fig. 12.

The design of the circuit included the following steps:

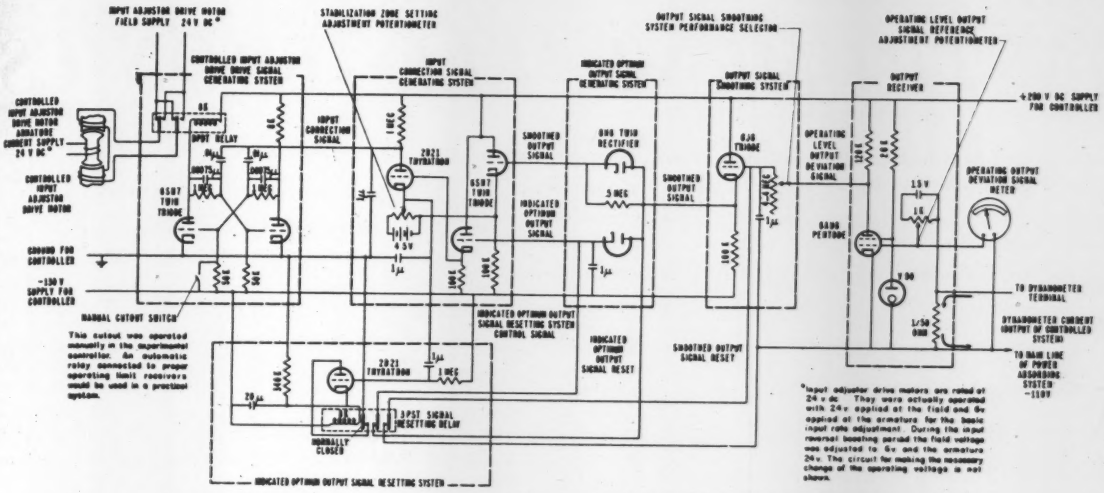

Fig. 19. Circuit diagram for a peak-holding optimalizing control for the CFR engine.

(1) The output hunting zone was estimated as three times the assumed output hunting loss.

(2) The static performance characteristic curves of the engine were used to find the corresponding input hunting zone for the estimated output hunting zone.

(3) The type and size of the output interferences of the engine were analyzed with engine-indicator records; with these data it was possible to estimate the tolerable magnitude of the interference in the smoothed output signal.

(4) The response delay of the engine dynamometer system (the output coupler), equal to 0.8 second, was determined experimentally. From the desired output-linear-group performance function and the known output-coupler performance function it was possible to determine the performance function of the output-signal-smoothing system and the corresponding response delay, which was also 0.8 second for the experimental test.

(5) The input-linear-group response delay of 0.3 second was determined experimentally. The sum of the response delays of the input linear group and the output linear group gave a total response delay of about 1.9 seconds for the complete system. The output hunting period was designed to be six times the total response delay of the complete system, or 12 seconds.

(6) The input hunting period was determined by multiplying the output hunting period by a factor of two. The input adjustment rate was determined from the input hunting period, and the input hunting zone determined in step number three.

(7) The recovery time of the system was obtained from the input rate and the performance characteristic curve, using methods described in the discussion of recovery time.

Fig. 20 shows a typical record obtained when the C.F.R. engine was controlled by a peak-holding optimalizing system. In this record, plot (a) gives the output deviation from the optimum output level, plot (b) shows the instants at which input drive reversals occurred, plot (c) shows the ignition timing, and plot (d) shows the variation of intake manifold pressure. All four of these plots have a common time axis, which is marked below plot (d). The complete test was divided into two sections by the vertical dashed

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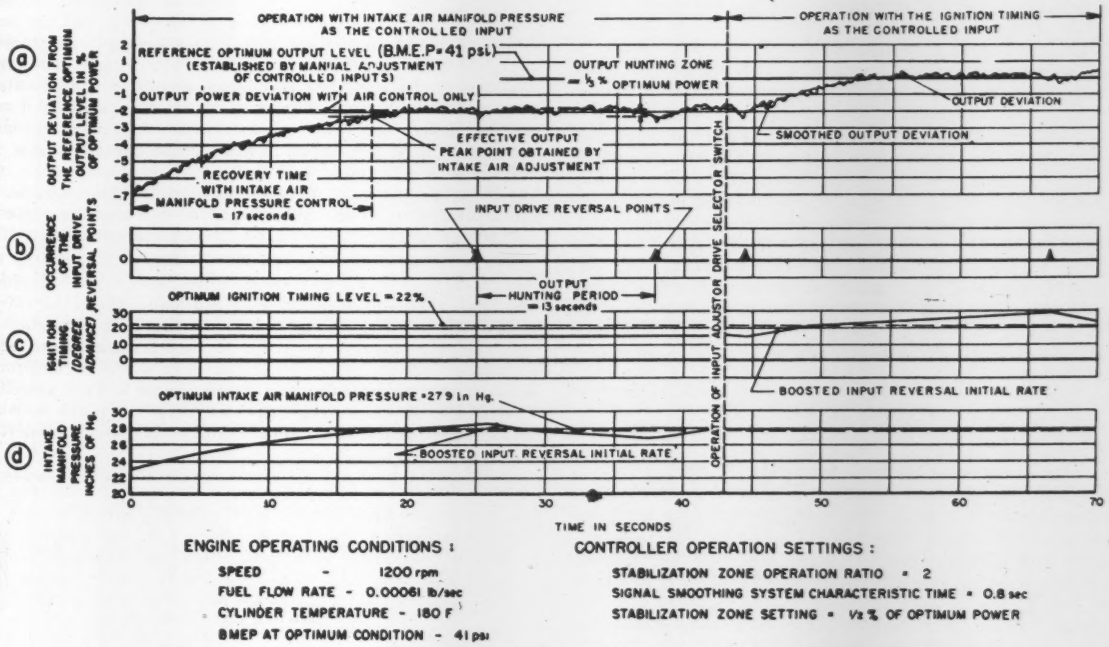
OPERATION WITH INTAKE AIR MANIFOLD PRESSURE AS THE CONTROLLED INPUT
OPERATION WITH THE IGNITION TIMING AS THE CONTROLLED INPUT
REFERENCE OPTIMUM OUTPUT LEVEL (B.M.E.P.=41 psi) (ESTABLISHED BY MANUAL ADJUSTMENT OF CONTROLLED INPUTS)
OUTPUT HUNTING ZONE = ½ % OPTIMUM POWER
OUTPUT POWER DEVIATION WITH AIR CONTROL ONLY
OUTPUT DEVIATION
SMOOTHED OUTPUT DEVIATION
EFFECTIVE OUTPUT PEAK POINT OBTAINED BY INTAKE AIR ADJUSTMENT
RECOVERY TIME WITH INTAKE AIR MANIFOLD PRESSURE CONTROL = 17 seconds
INPUT DRIVE REVERSAL POINTS
OUTPUT HUNTING PERIOD = 13 seconds
OPTIMUM IGNITION TIMING LEVEL = 22%
OPTIMUM INTAKE AIR MANIFOLD PRESSURE = 27.9 In Hg.
BOOSTED INPUT REVERSAL INITIAL RATE
OPERATION OF INPUT ADJUSTOR DRIVE SELECTOR SWITCH
TIME IN SECONDS
ENGINE OPERATING CONDITIONS :
SPEED - 1200 rpm
FUEL FLOW RATE - 0.00061 lb/sec
CYLINDER TEMPERATURE - 180 F
BMEP AT OPTIMUM CONDITION - 41 psi
CONTROLLER OPERATION SETTINGS :
STABILIZATION ZONE OPERATION RATIO = 2
SIGNAL SMOOTHING SYSTEM CHARACTERISTIC TIME = 0.8 sec
STABILIZATION ZONE SETTING = ½ % OF OPTIMUM POWER

Fig. 20. Performance of a CFR engine operating with the experimental optimalizing-control system.

INSTRUMENT ELECTRONICS

The amplifier is a basic electron-tube circuit. Important amplifier factors include classification, distortion, coupling, video amplifiers, bias methods, feedback, cathode followers, electrometer tubes, and noise level. The first three factors are presented in this installment.

By MILTON H. ARONSON
Managing Editor, *Instruments*

VIII. AMPLIFIER CIRCUITS

AN electronic amplifier consists of one or more vacuum tubes and associated circuits that increase a signal either in voltage or in current. A tube amplifies because a small grid voltage (the input signal) controls the plate current, which in turn produces a large *IZ* voltage (the output signal) across the plate load.

A basic triode amplifier circuit is shown in Fig. 8-1,A. The C battery maintains the grid at a negative potential with respect to the cathode. The signal to be amplified is shown in series with the grid-bias voltage, E_c. The plate

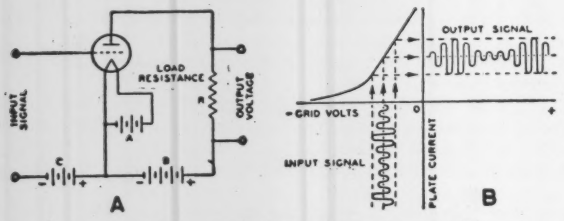

Fig. 8-1. Triode amplifier. A, circuit; B, operation.

load can be any device in the plate circuit through which the plate-current variations pass. The output signal is the *IR* or *IZ* signal produced across the plate load.

With no signal applied to the grid, there is a steady flow of plate current through the load, as determined by the bias, B supply, and load resistance. The signal voltage controls the current variations drawn from the B supply, which is the source of all plate current. The plate current increases when the grid goes less negative and decreases when it goes more negative. Thus there is a 180-degree difference in phase between input signal and output signal—that is one is at a positive peak when the other is at a negative peak.

As shown on the E_g-I_p curve in Fig. 8-1,B, the C battery selects the operating point of the tube. This point usually is selected on the linear portion of the characteristic curve. The steady flow of plate current through the load resistance determines the plate operating voltage, E_p. The plate operating voltage (the voltage difference between plate and cathode) is the B-supply potential minus the drop across the load. The potential *variations* across the load are the output signals, and should not be confused with the static operating potential of the plate, which usually is independent of signal voltage.

Classification of Amplifiers

According to Frequency

Amplifiers can be classified according to the frequency ranges over which they operate. The four general types are direct-current (d-c.), audio-frequency (a-f.), video-frequency, and radio-frequency (r-f.) amplifiers. A d-c. amplifier can amplify a d-c. signal. Audio-frequency amplifiers are designed to amplify a-c. signals from about 15 to about 15,000 cps.

Frequencies above 15,000 cps. are considered radio frequencies. The term "video frequency" refers to the frequencies in the pulse-type signals encountered in radar and television—from zero to about 4 Mc.

According to Use

When classified according to type of service, amplifiers are divided into two groups—*voltage amplifiers* and *power amplifiers*.

A *voltage amplifier* is designed to increase the size of the input signal voltage without regard to the power delivered to the load. Fig. 8-2 shows how the voltage gain of

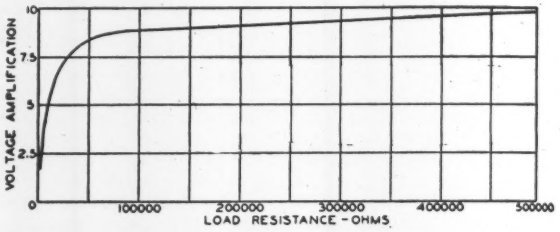

Fig. 8-2. Voltage amplification vs. load resistance for a triode having a mu of 10, a transconductance of 1000 micromhos, and a plate resistance of 10,000 ohms.

a tube varies with the load resistance. For high voltage gain, a large load resistance should be used. Note that the gain approaches (but does not reach) the mu of the tube for high load resistance. Most voltage amplifiers have a high load resistance so that a large voltage can be developed across the load.

A *power amplifier* is designed primarily to deliver power (high current) to the load, the voltage amplification being of secondary significance. Most power amplifiers have a low-impedance load that is selected either to give maximum power with minimum distortion or to give a desired value of plate efficiency. *Plate efficiency* is the ratio of output signal power to d-c. input power (plate current times plate voltage). A tube always receives more plate power from the B supply than it delivers as useful output power. The difference between the plate input power and the plate output power is power dissipated by heating the plate.

The vacuum tube delivers the output signal to the load. As explained previously, maximum power is delivered to the load when the impedance of the load equals the internal impedance of the source, which is the plate resistance of the tube. However, a low value of load resistance introduces amplitude distortion of the output signal. As a compromise, most triode power-amplifier stages have a load impedance that is two or three times greater than the plate resistance of the tube. Although a small amount of power is sacrificed

ANSWERS TO QUIZ VII.—RECTIFICATION

7-1.	(a)	7- 6.	(d)	7-11.	(b)	7-16.	(a)	7-21.	(a)
7-2.	(d)	7- 7.	(b)	7-12.	(a)	7-17.	(a)	7-22.	(c)
7-3.	(d)	7- 8.	(d)	7-13.	(d)	7-18.	(b)	7-23.	(b)
7-4.	(c)	7- 9.	(a)	7-14.	(b)	7-19.	(d)	7-24.	(a)
7-5.	(b)	7-10.	(b)	7-15.	(c)	7-20.	(c)	7-25.	(c)

Test Items for VIII.—Page 360

because the load impedance is higher than the source impedance, the amplitude distortion is less. The correct value of load impedance for pentodes is designated in tube manuals.

According to Bias

In addition to classification by frequency and use, vacuum-tube amplifiers can be classified according to the bias voltage applied to their grids—that is, according to the portion of the a-c. signal cycle during which plate current flows. When classified according to bias, amplifiers are class A, class AB, class B, and class C.

Class-A amplification.—If the grid of an amplifier tube is biased so that plate current flows throughout the cycle of the a-c. signal voltage, the stage is called a class-A amplifier. Class-A operation is illustrated on the E_g-I_p characteristic curve of Fig. 8-1,B. Note that plate current flows during both positive and negative half cycles of the a-c. signal applied to the grid. Class-A operation usually is used to produce a plate-current waveform that is an exact reproduction of the signal-voltage waveform. Therefore,

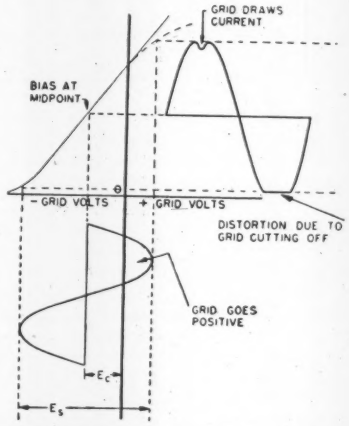

Fig. 8-3. Distortion in class-A amplifier caused by excessive signal.

the tube must be biased so that it operates on the linear portion of its E_g-I_p curve. Distortion occurs in a class-A amplifier when the tube is biased incorrectly or when too great a signal is applied to the grid. Fig. 8-3 shows how too large a signal produces distortion on both positive and negative peaks. The distortion on negative peaks is caused by the tube cutting off; the distortion on positive peaks is caused by the grid drawing current.

Class-A amplifiers are characterized by low distortion, low power output, and low plate efficiency (20 to 35 percent). Voltage amplifiers usually are operated class A.

Class-B amplification.—If the grid of an amplifier tube is biased to cut-off so that plate current flows only during the positive half cycles of the applied a-c. signal voltage, the tube is said to be operated as a class-B amplifier (Fig. 8-4,A). As plate current flows only during the positive half cycles, the plate-current waveform is not a replica of the signal-voltage waveform; the tube acts like a half-wave rectifier.

The signal voltage applied to the grid of a class-B amplifier is usually much greater than that applied to the grid of a class-A amplifier. The applied signal may be so large that the grid goes positive with respect to the cathode and draws grid current.

Class-B amplifiers are used in audio amplifiers because they have an efficiency of about 50 to 60 percent. They have this high efficiency because there is no plate current (and hence no plate power) when there is no input signal. This means less plate dissipation and more power output for a given power input. They generally are used where it is desired to develop a relatively large power output in the load circuit.

In order to avoid the large amount of distortion in the output of a single-tube class-B amplifier, two class-B tubes often are arranged in a *push-pull* amplifier circuit, as shown in Fig. 8-5. One tube operates during the first half cycle of the a-c. signal voltage; the other tube operates during the second half cycle. The action of the push-pull amplifier is similar to that of the full-wave rectifier circuit. As plate current flows during the first half of a cycle in one tube and during the next half of the cycle in the other tube, the plate-current waveform in the load circuit is a signal with low distortion.

Push-pull class-B amplifiers also can be used successfully with little distortion in a single-tube radio-frequency amplifier if the load of the tube is a tuned tank. The "flywheel" action of a tank circuit at resonance keeps the distortion small—that is, the inductive and resonant action keeps current flowing smoothly and sinoidally even when the tube cuts off for a portion of its cycle.

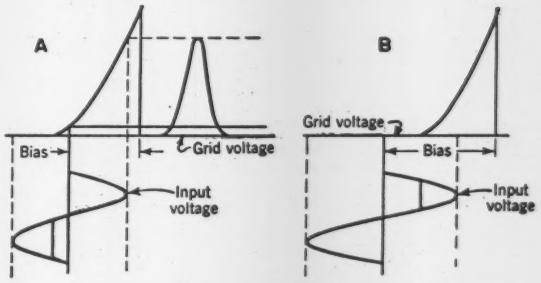

Fig. 8-4. Amplifier operation. A, class B; B, class C.

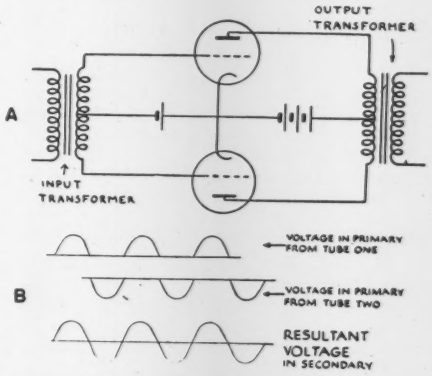

Fig. 8-5. Push-pull class-B amplifier and output.

Class-AB amplification.—It is possible to compromise between the low distortion and low efficiency of class-A amplification and the relatively high efficiency and high distortion of class-B operation. The comprise is made by biasing the amplifier circuit so that it operates halfway between class A and class B—that is, the tube is biased heavily but not to cut-off. This is known as class-AB amplification. If the a-c. signal voltage applied to a class-AB amplifier is small enough to keep grid current from flowing, the resultant operation is called class AB_1. If the applied signal is great enough to cause grid current to flow during the positive peaks of the signal-voltage cycle, the resultant operation is called class-AB_2 amplification.

Class-C amplification.—If the bias applied to the grid of an amplifier stage is appreciably greater than the cut-off value, the tube is operated as a class-C amplifier (Fig. 8-4,B). Plate current flows only during the portion of the positive half cycle of the applied a-c. signal voltage in which the signal is greater than the cut-off bias of the tube.

Almost all r-f. power-amplifier circuits in radio transmitters are operated class C. The parallel-tuned circuits used as plate loads in these amplifiers change the pulsating output waveform into a sinoidal waveform because of flywheel effect, as for class-B amplifiers. Class-C operation is very efficient—70 to 75 percent. The efficiency is high

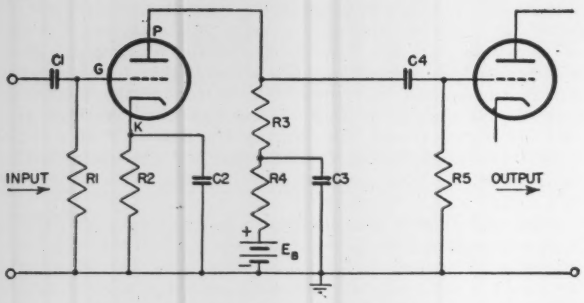

Fig. 8-6. RC-coupled amplifier stages.

because plate current flows only for a small part of each cycle.

Distortion

Distortion in amplifiers can be of three types—amplitude, frequency, and phase distortion. The effect of any distortion is to make the output signal differ in shape from the input signal. An amplifier can have any one or all three types of distortion.

Amplitude distortion results from operating on the non-linear portion of the characteristic curve, as shown in Figs. 8-3 and 8-4. In distortion-free class-A signal amplifiers the bias voltage and the signal voltage should be such that the signal voltage drives the grid only over the linear portion of the curve.

Frequency distortion occurs when all the frequencies in the input signal are not amplified equally in the amplifier. This distortion can be minimized by designing the amplifier so that it amplifies all important frequencies equally. This is done primarily by choice of plate load.

Phase distortion occurs when the phase relations of the different frequencies contained in the output signal are shifted so that the output waveform differs from the input waveform even though all frequencies are amplified equally. Phase and frequency distortion can be caused by improperly designed coupling networks.

Coupling

Most electronic circuits need more than a single stage of voltage or power amplification. To obtain greater gain, several stages are connected in series. As the output of one stage becomes the input of the succeeding stage this arrangement is called a *cascade* amplifier. A 3-stage cascade amplifier, each stage of which has a gain of 10, has a total gain of 1000.

A-f. and r-f. amplifiers use different methods for coupling amplifier stages. There are several methods of coupling, each of which has certain advantages and disadvantages. The basic methods are (1) resistance-capacitance coupling, (2) impedance coupling, (3) transformer coupling, and (4) direct coupling.

Resistance-capacitance Coupling.

Resistance-capacitance (RC) coupling is one of the most widely used methods for coupling audio and video voltage amplifiers. An RC-coupled amplifier is illustrated in Fig. 8-6. Capacitor C_4 and resistor R_5 are the coupling units.

A small signal voltage applied to the grid of the first stage is amplified into large voltage variations across load resistance R_3 in the plate circuit. Coupling capacitor C_4 couples the a-c. signal from the plate of the first stage to the grid of the second stage. The capacitor also prevents the d-c. voltage on the plate of the first stage from reaching the grid of the second. Grid resistor R_5 provides a d-c. path to ground for electrons that collect on the grid side of the coupling capacitor. The R_4-C_3 network is a decoupling network, which will be described later.

The chief advantage of a resistance-capacitance-coupled amplifier is ability to amplify all signals in a wide range of frequencies. This is shown by the frequency-response curves for a typical RC-coupled audio-frequency amplifier (Fig. 8-7). The frequency scale, plotted horizontally, is

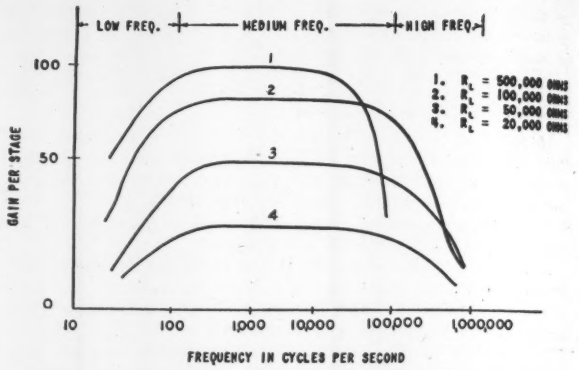

Fig. 8-7. Effect of load resistance on amplification at various frequencies.

logarithmic in order to allow a wide range of frequencies to be plotted. The separate curves are made for various values of load resistance (R_3 in Fig. 8-6).

If the gain of the stage is to be large, the plate-load resistor should be as large as possible. However, Fig. 8-7 shows that a large load resistance gives high amplification but poor high-frequency response. A low value of plate load gives good high-frequency response but weak amplification. In practice, a compromise is made between adequate frequency response and reasonable amplification.

The drop in response at the low-frequency end of the curve is caused by reactance of the coupling capacitor, which becomes large at low frequencies. The drop in response at high frequencies is caused by the interelectrode and distributed capacities, which shunt the higher-frequency signals to ground. The response can be improved by compensation techniques, which are described later.

The capacitance of the coupling capacitor should be large to avoid the loss of low-frequency signals. However, too large a capacitor cannot be used because large signals cause the grid to attract electrons which charge the capacitor, make the grid go too negative, and cut off the tube until the charge leaks off the capacitor. A tube cut off in this manner is said to be "blocked." As a large capacitor takes a long time to discharge through the grid resistor, a large capacitor cannot be used because the tube would be blocked for a long time. Thus the value of the coupling capacitor and the grid resistor is a compromise to allow accumulated charge to leak off rapidly and yet avoid the loss of low-frequency signals.

The chief advantage of resistance-capacitance coupling in amplifiers is equal amplification (flat frequency response) over most audio frequencies. Other advantages are cheapness, compactness, and ruggedness. A disadvantage of RC coupling is that there is no voltage step-up in the coupling circuit, as can be obtained by transformer coupling.

Impedance Coupling

Impedance coupling is like RC coupling except that the former uses an inductor as the plate load of the amplifier stage, as shown in Fig. 8-8. The advantage of using an inductor instead of a resistor is that the d-c. resistance of the inductor is low. Thus, the d-c. plate current causes little voltage drop across the low resistance of the inductor,

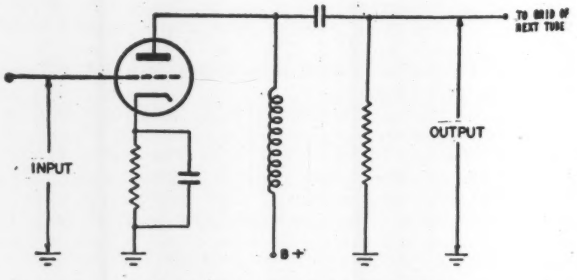

Fig. 8-8. Impedance-coupled amplifier.

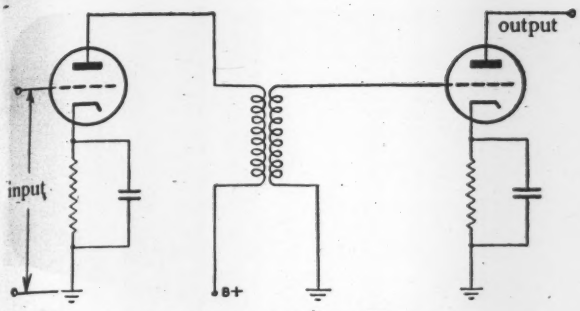

Fig. 8-9. Transformer-coupled amplifier.

yet the impedance of the inductor to the a-c. signal is large enough to yield satisfactory gain. The advantage of low d-c. drop across the plate load is that more B voltage is available for use in the tube. Thus the tube can have a higher operating plate voltage and higher gain with the same B supply.

A disadvantage of impedance coupling is that the amplification for various frequencies is not uniform. The inductive reactance of the coil is small for low-frequency signals and large for high-frequency signals. Thus, impedance coupling gives greater amplification as the signal frequency is increased.

Transformer Coupling

As shown in Fig. 8-9, transformer coupling uses an a-f. or r-f. transformer for coupling the signal between stages. The primary of the transformer is the plate load of the first stage. The secondary voltage is applied to the grid of the following stage. Like impedance-coupled amplifiers, transformer-coupled amplifiers have the advantage that plate current causes low d-c. voltage drop across the primary. Another advantage is that if the secondary has more turns than the primary, the output voltage is stepped-up in direct proportion to the turns ratio. Thus voltage gain is obtained from the coupling transformer.

Transformer coupling is particularly adaptable for coupling push-pull power amplifiers because a transformer can supply voltages that are equal in amplitude and 180 degrees out of phase, as shown in Fig. 8-5.

The frequency response of most transformer-coupled amplifiers is poor for both high and low frequencies. The loss in amplification at low frequencies is caused by the low reactance of the transformer primary at low frequencies. Amplification falls off sharply at the higher frequencies because of distributed capacity, leakage inductance, and a-c. losses in the iron core. Also, there may be one or two frequencies at which the inductance of the transformer windings resonates with stray capacitances of the circuit. This causes increased amplification at the resonant frequencies.

In class-AB_2 and class-B a-f. amplifier circuits, a more important requirement necessitates the use of transformer coupling. Most power amplifiers have such large signals applied that the grids are driven positive for part of the signal cycle. When this occurs, the tube draws grid current.

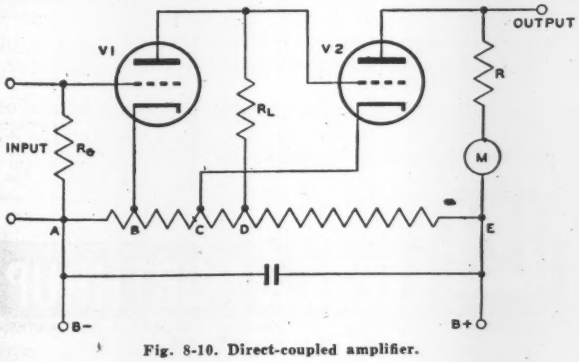

Fig. 8-10. Direct-coupled amplifier.

If the grid circuit of the tube has a resistor, the grid current flowing through this resistor produces a bias voltage that can reduce the power output, cause distortion, or block the stage. The d-c. resistance of the grid circuit of such amplifiers, therefore, must be kept small. The low d-c. resistance of the secondary winding of the transformer satisfies this requirement. Thus, transformer coupling always is used for class-AB_2 and class-B a-f. power-amplifier circuits.

Transformers are used commonly for impedance matching. To obtain the maximum transfer of power from the plate circuit of the preceding stage to the grid circuit of the following stage, the output impedance of the first stage must match the input impedance of the second stage. This requirement is met conveniently and efficiently by a transformer with the proper turns ratio.

Direct Coupling

In the coupling circuits that have been considered, the coupling device isolates the d-c. voltage of the plate circuit from the following grid circuit and allows only the a-c. signal to pass through the coupling device. In a direct-coupled amplifier the plate of one tube is connected directly to the grid of the next tube without any blocking or coupling device, as shown in Fig. 8-10. As the plate of the first tube is more positive in voltage than its cathode, the grid of the second tube also is at a positive potential. As this grid must have a negative voltage with respect to its cathode, the cathode must be connected to a potential that is more positive than the grid. This can be done by a special voltage-divider network, as shown in Fig. 8-10.

The voltage-divider is selected so that point C is slightly more positive than the plate of the first tube. This produces proper bias for the second tube. Note that both tubes can use only a part of the total B voltage. The plate voltage available for the first tube is the voltage between B and D. The plate voltage for the second stage is from C to E. The voltage divider can be eliminated by using separate B supplies for each stage.

When the tube voltages are adjusted to give class-A operation, the circuit is a distortionless amplifier, the frequency response of which is uniform over a wide range from d.c. to many kilocycles per second. Direct-coupled amplifiers are used to amplify very low frequencies because the impedance of the coupling element does not vary with frequency, as in other type couplings.

Chopper-type d-c. amplifiers.—An inherent disadvantage of direct-coupled amplifiers is instability. The d-c. operating plate voltage of a tube drifts slightly because of temperature changes, power-supply variations, etc. In a-c. coupled amplifiers, the d-c. operating plate voltage is blocked by the coupling capacitor or inductor, but in direct-coupled amplifiers the drift is a serious source of error that becomes serious in high-gain amplifiers.

To eliminate this source of error, most high-gain d-c. amplifiers use the *chopper*, or *breaker*, principle. The low-voltage d-c. signal to be amplified first is "chopped" by a vibrator to produce a pulsating d-c. signal. This signal then is amplified in a conventional a-c. amplifier and is rectified at the output if a d-c. output is desired.

To be continued

TEST ITEMS FOR—VIII. AMPLIFIER CIRCUITS

8-1. The operating plate potential of an amplifier stage usually is independent of
(a) signal voltage
(b) bias voltage
(c) B-supply voltage
(d) load resistance

8-2. The term "video-frequency band" refers to frequencies
(a) above 15,000 cps. only
(b) from 15 to about 15,000 cps. only
(c) from zero to about 4 Mc. only
(d) above 4 Mc. only

8-3. The term "audio-frequency band" refers to frequencies
(a) above 15,000 cps. only
(b) from 15 to about 15,000 cps. only
(c) from zero to about 4 Mc. only
(d) above 4 Mc. only

8-4. The term "radio frequency" refers to frequencies
(a) above 15,000 cps. only
(b) from 15 to 15,000 cps. only
(c) from zero to 4 Mc. only
(d) above 4 Mc. only

8-5. A voltage amplifier differs from a power amplifier in that the former has
(a) better frequency response
(b) higher load impedance
(c) fewer stages
(d) all the above

Continued on page 360

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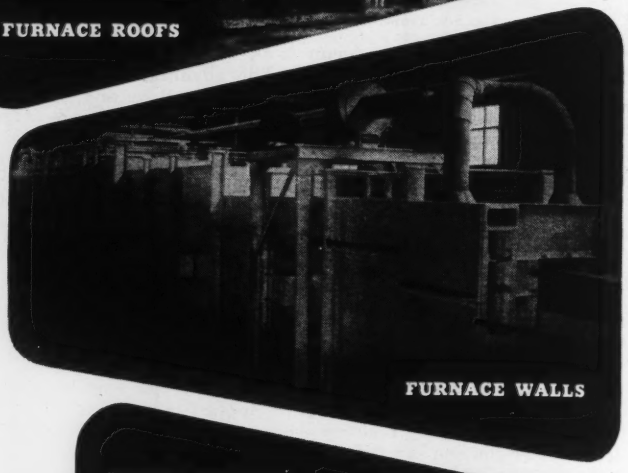

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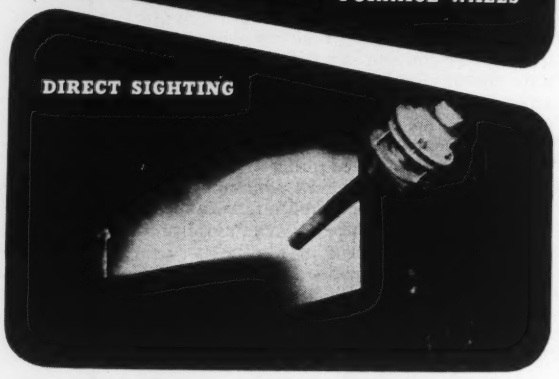

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TABLE OF CONTENTS

Sections Data 334
Continuous Recording Electrometric Titrometer, by H. E. Hallikainen and D. J. Pompeo 335
Electrical Transmitting and Transducing of Process Measurements, by C. G. Roper 338
Control Valve Symposium 341
Employment Service 341
Cleveland Committee Meeting 341
Papers for 1952 Conference 341
New York Section Annual Banquet 341
Cleveland Exhibit Largest 342
Hotel Reservations—Cleveland 342

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Fourth Friday, Meeting 7:30 P.M., Electric Bldg., Georgia Power Co.

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G. B. Greer, 631 East 36th St., Baltimore 18, Md. Tel: CHesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

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April 9, Dinner 6:30 P.M., at Knotts Berry Farm. Meeting 8 P.M.—Inspection tour of Brea Research Center, Union Oil Co. of Calif.

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HOUSTON
I. K. Farley, Brown Instrument Co., 2123 Travis St., Houston, Texas, Tel: Charter 2511.
Last Monday, Meeting at 8:00 P.M., University of Houston Library Building.

KANSAS CITY
J. C. Brous, 8827 Maiden Lane, Kansas City 5, Mo.
First Tuesday, Meeting at 7:30 P.M., U. of Kansas City, Science Bldg., Rm. 106.
Apr. 8, Subject: Electro-Mechanical Measurement, Amplification, and Transmission. Speaker: Garland Roper, Manning, Maxwell and Moore.

LOUISVILLE
C. M. Bosworth, 5336 Westhall Ave., Louisville, Ky.
First Monday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
L. E. Henne, Bristol Co. of Canada Ltd., 712 Dominion Square Bldg., Montreal, Quebec, Canada Tel: UNiversity 6-4725.
Last Monday, 8:00 P.M., Mechanic's Institute.

NEW JERSEY
L. H. Ballinger, 2371 Channing Ave., Westfield, N. J. Tel: Westfield 2-0765M
First Tuesday. Meeting at 8:00 P.M., Essex House, Newark.
April 1, Symposium on "The Use and Application of Control Valves."

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 520 South 14th St., New Hyde Park, N. Y. Tel: FI-7-0645.
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

NIAGARA FRONTIER
Mrs. James L. Martin, 34 Manning Rd., Eggertsville 21, N. Y. Tel: WIndsor 0087
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
Bert L. Anderson, 1951 47th Ave., San Francisco 16, Calif. Tel: SEabright 1-5030
Third Monday, Dinner 6:30 P. M., Meeting 8:00 P.M., Spengers Grotto, 1919-4th St., Berkeley.

NORTHERN INDIANA
J. Baum Beckman, 7145 Wicker Ave., Hammond, Ind. Second Tuesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.
Apr. 8, Subject: The Application of Plug and V-Port Valves. Speaker: From Fisher Governor Co.

OAK RIDGE
George Ritscher, 113 Gorgas Lane, Oak Ridge, Tenn. Tel. 5-1084
First Wednesday, Meeting at 7:30 P.M., Ridge Recreation Hall
April 2, Subject: Radioactive Isotope Tracer Techniques and Applications. Speaker: J. Kohl, Tracerlab, Inc.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside. Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
Bruno F. Loewen, Philips Chem. Co., Box 1526, Borger, Texas.
Third Tuesday, Meeting at 8:00 P.M.

PERMIAN BASIN
J. B. Jenkins, 509 South Ave. "C," Kermit, Texas. Tel: 3220
Second Tuesday, Meeting at 7:30 P. M., Gulf Oil Corp. Auditorium or Odessa College.

PHILADELPHIA
R. A. Trenner, Energy Control Co. Rm. 306, 3147 N. Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellevue-Stratford Hotel.

PITTSBURGH
W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa., Tel. Express 1-1330
Fourth Monday, Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.
April 3-4, Conference Sponsored by Pittsburgh Section ISA and Carnegie Institute of Technology, Subject: Instrumentation for the Iron and Steel Industry.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.
Mar. 25, Subject: Control Valves and Positioners. Speaker: From Fisher Governor Co.
April 22, Election of Officers. Film—"Principles of Automatic Control."

RICHLAND
T. H. Quinn, 1513 Goethals Dr., Richland, Wash. Tel: 7-8717
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., Foxboro Co., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Hamilton 1468.
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
L. J. Hall, 730 Talfourd St., Sarnia, Ont., Canada. Tel: EDgewater 2258.
Second Monday, 8:00 P. M., Y.M.—Y.W.C.A.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

SOUTHERN MICHIGAN
Lyle J. Draper, 2233 Oakland Dr., Kalamazoo, Mich.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516.
First Wednesday After First Monday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.
April 9, Subject: Electro-Mechanical Measurement, Amplification, and Transmission. Speaker: Garland Roper, Manning, Maxwell and Moore.

TOLEDO
P. H. Girkins, 418 Waggoner Blvd., Toledo 12, Ohio. Tel: LA 6505
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
James L. Williams, 2237 Bruce St. Kingsport, Tenn. Tel: 2079-L
Fourth Thursday, Civic Auditorium.

TULSA
S. M. Bagwell, 1544 E. 35th Pl., Tulsa 5, Okla. Tel: 7-6822
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.
Apr. 7, Subject: Electro-Mechanical Measurement, Amplification and Transmission. Speaker: Garland Roper, Manning, Maxwell and Moore.

TWIN CITIES
Jerome J. Schwab, Engineering Sales, 516 Guardian Bldg., St. Paul 1, Minn. Tel: GArfield 0601
Fourth Tuesday, Dinner at 6:30 P.M., Meeting 7:30 P.M., Rm. 353, Coffman Memorial Union, U. of Minn.

WASHINGTON
Edward C. Lloyd, 2105 Spencer Road, Silver Spring, Md. Tel: SH. 9340.
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
J. R. McCauley, 18073 Archdale, Detroit 19, Mich. Tel: KE 1-5289.
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
E. Avery Taylor, Taylor Instrument Co., Industrial Trust Bldg., Rm. 510, Wilmington, Del. Tel: 9814.
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

Continuous Recording Electrometric Titrometer

With Special Reference to Control of Gasoline Refining

K. E. HALLIKAINEN* and D. J. POMPEO*

UPON adoption by certain refineries of the solutizer process [1,2] for the removal of mercaptan sulfur from gasoline, a self-recording, semi-automatic mechanized electrometric titrometer[3] was developed to supplement the not-too-satisfactory doctor test[4]. The semi-automatic titrometer principle of operation is based on the method of potentiometric determination of mercaptans described by Tamele and Ryland[5] as modified by Lykken and Tuemmler[6].

This instrument requires the operator to place a measured amount of gasoline and reagent in a vessel and press a button to start the titration. The instrument then titrates to a given end point and records the quantity of conductive solution required which is converted directly to per cent mercaptan in the gasoline.

While this instrument performs satisfactorily for spot test measurements, a completely automatic on-stream instrument is desirable for some applications. Such an instrument† was constructed in 1948, consisting of two Zenith[7] pumps — one for pumping the liquid to be titrated at a constant rate and the other for pumping the titration liquid at a rate to keep the combined solution at an equivalence value. The rate of pumping the titration liquid was then recorded as the per cent mercaptan present.

Other Automatic Titrometers

A number of other automatic apparatus for recording titrations have been described in the literature. Kordatzke and Wulff[8] describe an apparatus which records the cell potential in terms of the quantity of reagent used. A commercial adaptation of this type of instrument is manufactured by Precision Scientific Company[9]. Shenk and Fenwick[10] have developed a titrometer which automatically stops an electrometric titration at a predetermined point. Keeler[11] describes one of the first continuous titration systems used for controlling the alkalinity of boiler feed water.

Sheen[12] describes several automatic titration systems using reciprocating plunger pumps for accurately metering both the sample and reagent. Austin, Turner and Percy [13] and Shaffer, Briglio and Brockman[14] describe automatic titrometers of the dead-stop end point type where the sample is continuously metered into a titrating vessel and the reagent electrolytically generated. This apparatus has been used for the determination of H_2S, SO_2 and mercaptans in gases.

Selection of Equivalence Value

The procedure for the usual manual titration is to disolve the sample in an alcoholic sodium acetate titration solvent and to titrate electrometrically with alcoholic silver nitrate solution, using as indicator the potential between a glass reference electrode and a silver sulfide indicating electrode. The titration to the mercaptan end point gives the mercaptan content.

Fig. 1 shows five of these manual titration curves with the end points indicated. The per cent weight of mercaptan as sulfur can then be calculated with the aid of the following formula:

Mercaptan, % wt as

$$S = \frac{(A)\ (N)\ 3.206}{W}$$

where

A = volume of silver nitrate solution, milliliters, used in titrating the sample.

N = normality of the silver nitrate solution.

W = weight of sample, grams.

From an inspection of Fig. 1, it can be seen that if the end point were taken as plus 250 mv, the error made in the calculation of mercaptan content would be less than 1 per cent. This is what is done in the semi-automatic titrimeter[3]. However, in the automatic titrometer the end points are taken along line A-B and the correction made in the calibration of the recorder.

General Description

The instrument is shown schematically in Fig. 2. It consists of:

(1) Means of metering test liquid.
(2) Means of metering titrating liquid.
(3) Titrating vessel.
(4) Electrometer for determining glass and silver electrode potential.
(5) Amplifier to supply the quadrature voltage for the titration solution pump motor.
(6) Recorder and d-c generator for recording the titration solution pump speed.

Means of Metering Test Liquid: The test liquid is metered with a Zenith gear pump driven at a constant rate with a synchronous motor. When gasoline is the test liquid, a differential pressure regulator is added to the system to reduce vaporization. This vaporization is caused by the heat generated in the pump due to the extremely close clearance of rubbing parts (in certain parts, amounting to 25 micro inches) and to the poor lubricating qualities of gasoline. In addition, the differential-pressure regulator elimiates the necessity of reducing the normal plant pressure to a low value to avoid excessive slippage across the pump.

The differential pressure regulator,

*Shell Development Company, Emeryville, California.

†Patent applied for.

Presented before the Sixth Annual Conference of the Instrument Society of America, at Houston, Texas, Sept. 10-14, 1951.

Statements and opinions expressed herein are those of the authors, and not necessarily those of the Society.

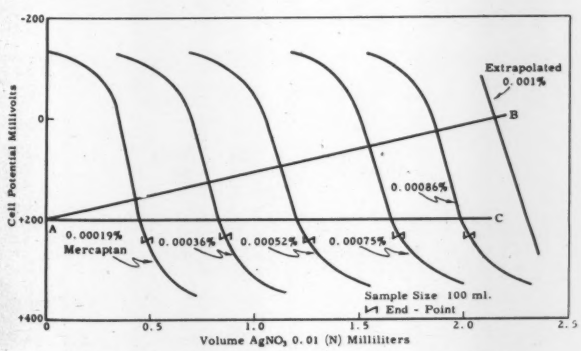


Fig. 1 Manual Titration of Mercaptan in Gasoline

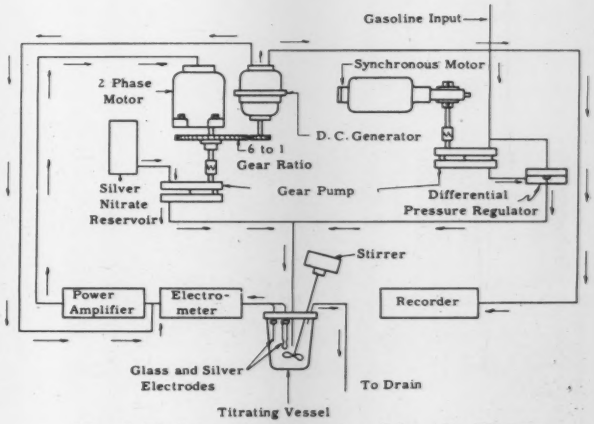
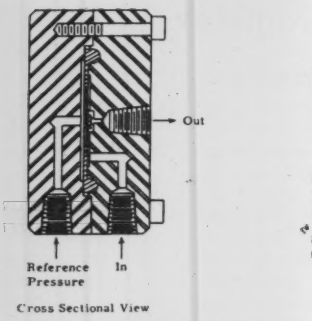


Fig. 2 Electrometric Titrometer—Schematic Diagram



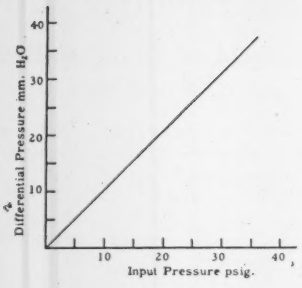


Fig. 3 Differential Pressure Regulator and Characteristics

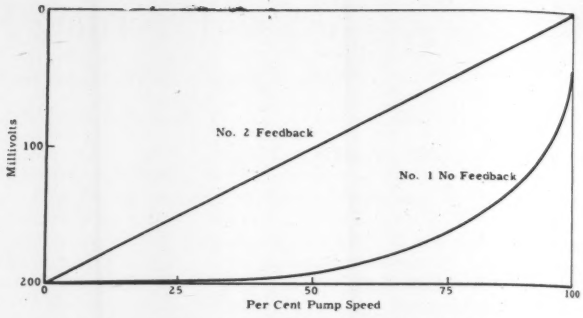


Fig. 4 Relation Between Pump Speed and Input Voltage

shown in Fig. 3 with its operating characteristics, was specially constructed since none were available commercially. The pump is connected in the system so that it is under plant operating pressure and the pressure drop across the pump is small.

The synchronous motor used for driving the pump has a built-in gear train reducing the speed to 15 rpm when operated from a 60-cycle source of power. With this operating speed, the pump delivers 4.5 ml per minute of gasoline to the titrating vessel. If the motor is driven from a constant frequency source, variations in speed can be neglected.

A 200 mesh screen filter is provided in the inlet of the pump to prevent foreign matter from damaging or clogging the pump.

Means of Metering Titrating Solution: The titrating solution is also metered with a Zenith gear pump, but no special provision for reducing the pressure drop across the pump is necessary since the inlet pressure is in the order of 1/2 psig. This pump is driven by a two-phase motor at a rate sufficient to keep the combined solution at a pre-determined equivalence value. One of the motor fields is connected directly to the 60-cycle power source and the other receives its power from the amplifier which is excited by the electrometer.

The titrating solution supply is contained in a one-gallon glass vessel painted black to protect the silver nitrate against photo-chemical action of sunlight. A narrow vertical strip is left unpainted so that the liquid level can be observed.

Titrating Vessel: The titrating vessel, constructed of type 316 stainless steel, has a volume of approximately 20 ml. It houses silver and glass electrodes and a stirrer which is driven by a small induction motor. Electrode and stirring motor shafts are all provided with pressure type seals so that, if necessary, the cell can be operated under pressure.

Both silver and glass electrodes are insulated electrically from the titrating vessel; thus the combined solution is at ground potential.

Electrometer: The electrometer circuit (Fig. 7) is similar to the one described by Penther and Rolfson[15]. It is used to amplify the small currents of the glass and silver electrodes.

A source of bias voltage is also incorporated in the electrometer circuit so that at its output terminals a difference voltage between this bias and the electrode voltage appears.

Power Amplifier: A Brown amplifier is used to amplify the difference voltage from the electrometer and to drive the pump motor at a speed proportional to this voltage.

Recorder and D-C Generator: A d-c generator is mechanically coupled to the titration solution pump, thereby generating an emf proportional to the pump speed. This emf is then recorded by a recorder calibrated directly in per cent mercaptan. In addition, a portion of this emf is used as inverse feedback for the power amplifier to improve the linearity and stability of the amplifier.

Method of Maintaining Equivalence Value

The small current of the electrodes is amplified with the electrometer amplifier, which also supplies a source of bias voltage, so that at its output terminals a difference voltage is obtained between the bias voltage and electrode voltage. This difference voltage is further amplified by a power amplifier and then supplied to the quadrature

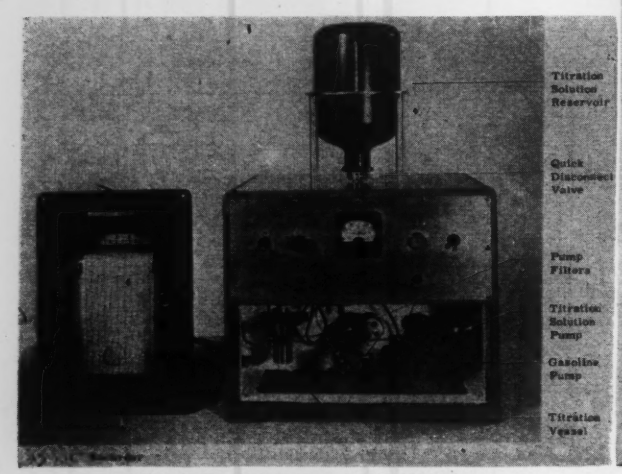


Fig. 5 Front View Mercaptan Analyzer

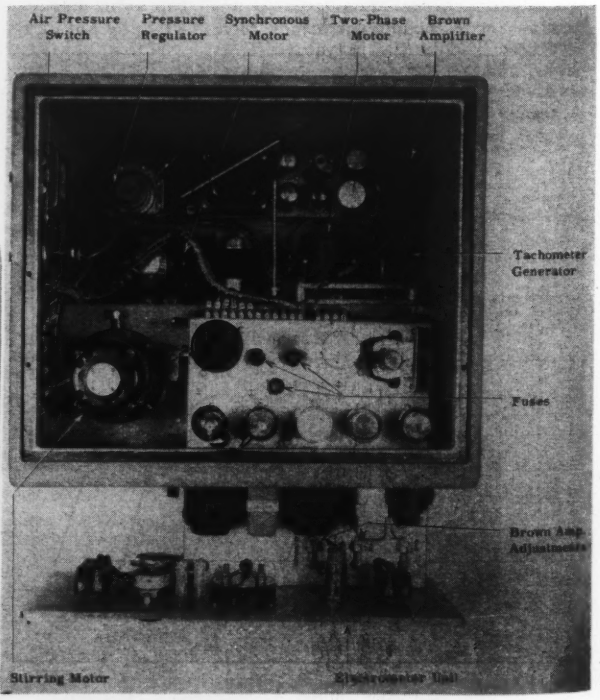


Fig. 6. Top view Mercaptan Analyzer with Cover Removed.

field of the titration solution pump motor.

If the bias voltage is adjusted to minus 200 millivolts and known voltages from 0 to plus 200 millivolts are applied to the input of the electrometer, the pump speed versus input voltage characteristics would be as shown in Curve 1 of Fig. 4. However, if a portion of the d-c generator voltage is fed back as inverse feedback to the power amplifier, this non-linear relationship is transferred to the linear one shown in Curve No. 2 of Fig. 4. In addition, the application of the inverse feedback considerably improves the stability of the power amplifier.

Returning to Fig. 1, the representa tive titration curves shown, like cor responding curves not shown, have straight portions between minus 50 mv and plus 250 mv. Assume at the moment that the titrometer selects its equivalence value along line A-B. At full scale value of mercaptan (0.001 per cent by weight), the titration pump must run at full speed, supplying 2.2. ml of 0.01 N silver nitrate for every 100 ml of gasoline.

For full speed of the pump, an electrode voltage of zero is required. Similarly, if 0.0005 per cent mercaptan is present, the titrating pump must run at 50 per cent speed which requires an electrode potential of plus 100 mv. The line A-B of Fig. 1, with its origin at plus 200 mv, is identical to Curve No. 2 of Fig. 4 when speed is converted to volume units.

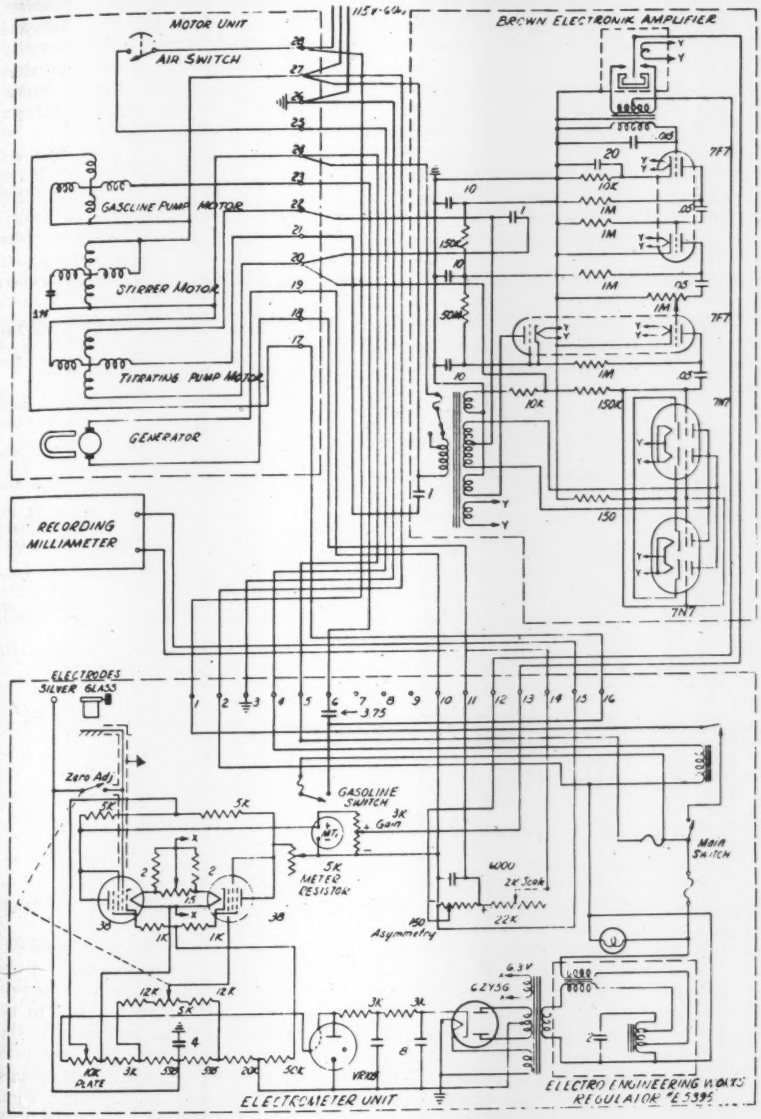


Fig. 7 Wiring Diagram

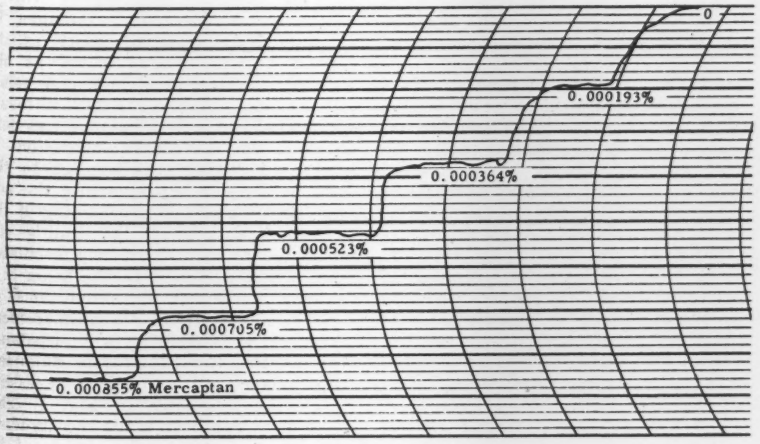


Fig. 8. Calibration Curve

Special Design Features

Fig. 5 and 6 show front and top view of the instrument; Fig. 7 is the wiring diagram.

All the electrical components are housed in a cast aluminum box which is pressurized with air as a safety precaution when used in hazardous locations. A pressure reducing valve is used to reduce the plant air pressure to approximately two inches of water pressure. To assure that the instrument is not operated without positive pressure inside the case, a diaphragm-operated mercury switch is inserted in series with the incoming power lines.

All components in contact with gasoline — such as pump, titrating vessel, and differential pressure regulator — are housed in a separate compartment open to the atmosphere.

A quick disconnecting fitting with automatic shut-off is provided between the pump and titrating solution reservoir.

Titration Solution

To avoid the need for an extra pump, the alcoholic sodium acetate solvent and silver nitrate solution were combined. This solution is made by dissolving 25 grams of c.p. sodium acetate trihydrate in 200 ml of oxygen-free distilled water and then pouring it into 3 liters of ethanol 3A. After it is thoroughly mixed, silver nitrate is added. The quantity of silver nitrate depends upon the range desired; for example, a range of 0-0.001 per cent mercaptan by weight requires 7 ml of 0.1 N silver nitrate. Higher ranges require proportional quantities of silver nitrate.

For ranges higher than 0.005 per cent mercaptan, it is recommended that the gasoline be porportionally diluted with low mercaptan gasoline and the resulting mixture analyzed with the instrument. If the range of the instrument is increased much beyond 0.005 per cent mercaptan by increasing the quantity of silver nitrate in the titrating solution, a precipitate of silver acetate is formed in the titrating vessel which renders the solution useless.

Installation

The installation of the instrument is relatively simple. Connections to the gasoline source, drain, and air are made with 3/16-inch tubing and the power connection with conduit or with three-conductor rubber-covered cable.

Adjustment and Maintenance

The adjustment procedure consists of setting the bias, plate voltage, power amplifier gain, and recorder sensitivity and assymmetry. Aside from a daily check of the bias setting, these adjustments require no further attention except when the electrodes or pumps are replaced.

Once weekly the glass electrode should be replaced with a spare electrode. The old electrode may be cleaned by immersing in cold chromic acid cleaning solution, then rinsed and stored in water to soak. The silver electrode should be cleaned at the same time by burnishing it with No. 00 emery cloth.

Once monthly the titration solution pump should be taken apart, silver removed if any has precipitated, and the pump lubricated with a neutral oil and reassembled.

If when checked against a manual titration the instrument reads low or high (because of pump wear, etc.), correction can be made by proportionally increasing or decreasing the silver nitrate concentration of the titration solution.

For calibration of the instrument in the laboratory a special sampler consisting of five pressurized reservoirs connected to a common manifold with a cut-off valve between each reservoir and manifold, was used since the gasoline sample must be under pressure. Typical calibration results are shown in Fig. 8. In this calibration the recorder readings were linear and the results obtained agreed with manual titration to better than $\pm$ 2 per cent.

Performance

The automatic titrometer is now in operation in a refinery for measuring the mercaptan content of a doctor-treated gasoline. So far operation has not been for a sufficiently long time to provide results of long term performance, particularly as to the amount of maintenance required under plant operating conditions. However, no difficulties have arisen so far, and it is expected that the instrument will continue to be an aid to the operators in detecting plant upsets and minimizing their effects, thereby producing a better quality of product.

References

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2) D. L. Yabroff and E. R. White, *Ind. Eng. Chem.*, 32, 950-3 (1940).

3) D. J. Pompeo, C. J. Penther and K. E. Hallikainen, *Instruments*, 16, 402-3, 440, 444 (1943).

4) "Doctor" Test, I.P.-30/44.

5) M. W. Tamele and L. B. Ryland, *Ind. Eng. Chem.*, Anal. Ed., 8 16-9 (1936).

6) L. Lykken and F. D. Tuemmler, *Ind. Eng. Chem.*, Anal. Ed., 14, 67-9 (1942).

7) Manufactured by Zenith Products, 58 Chestnut Street, West Newton 65, Massachusetts.

8) W. Kordatzki and P. Wulff, Z *Anal. Chem.* 89, 241-56 (1932).

9) Precision Scientific Company, 3737 West Cortland Street, Chicago, Illinois.

10) W. E. Shenk and F. Fenwick, *Ind. Eng. Chem.*, Anal. Ed., 7, 194-7 (1935).

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12) R. T. Sheen, *Instruments* 22, 442-7 (1949).

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14) P. A. Shaffer, Jr., A. Briglio, Jr., and J. A. Brockman, Jr., *Anal. Chem.* 20, 1008-14 (1948).

15) C. J. Penther and F. B. Rolfson, *Ind. Eng. Chem., Anal. Ed.*, 15, 337-40 (1943).

Electrical Transmitting and Transducing of Process Measurements

By C. GARLAND ROPER*

TO review the history of process instrumentation, we note the original use of equipment mounted instruments as an appropriate beginning. While these instruments served their basic function, the user was handicapped by the necessity for visiting the instrument location on the equipment to observe the process measurement. The design of the processing equipment was compromised with the requirements for instrument accessibility.

Recognizing accessibility needs, lead quickly to the use of panels with the instruments grouped together and connected to the equipment with pressure piping or transmission capillary. Examples of this instrumentation are piped gauges and capillary connected thermometers.

The introduction of electrical instruments extended the use and scope of central control panels. Pneumatic instruments, using compressed air to boost the measurement signal for transmission and control, carried still further the growth and efficiency of process operation.

As we review this history, we observed a need for improved correlation of mechanical and electrical measurements. Since most indication and control functions require mechanical work, a simple relating of electrical and mechanical energy would permit the process operation to add the advantage of high speed electrical communication. The history shows the communication is an essential function for effective process operation and control.

Recognizing these objectives, work was directed towards simplifying the task of combining the advantages of electrical and mechanical measurements. From a study of process measurement, it was evident that almost any measurement could be readily converted to either mechanical motion or direct current. These two forms of signal energy are not only compatible with the requirements for simplicity, but they suggested the galvanometer as the logical tool for their correlation. Furthermore, accurate transducing of mechanical and electrical functions with the galvanometer structure would permit design of measurement control systems with direct current as a signal and communication medium. In addition to the instantaneous response, such a system would permit control function computation in direct current, while minimizing the problem of inductance and capacitance in transmission circuits.

In seeking to develop a suitable electro mechanical measurement transducer based on the galvanometer principle, consideration was given to two fundamentals of measurement: One, the instrument should take the minimum of power from the phenomena to be measured; two, the output signal should be compared as directly as possible to the input signal with a minimum of intermediate linkages. To accomplish these stated objectives, the Kelvin balance was selected as the primary measuring element for relating the electrical and mechanical measurements. The Kelvin balance was next modified for automatic operation. A calibrated spring was applied to the balance for use in converting the mechanical motion to force loading of the pivoted beam. Next, the tuning circuitry of a high frequency oscillator was located adjacent to the beam in a manner to detect the conditions of balance of the beam for measurement purposes. This modified Kelvin balance was named the "Microsen Balance". The balance as applied to pressure measuring is shown in Fig. 1. This component has been made the standard measuring element of a group of in-

*Manning, Maxwell & Moore, Inc., Bridgeport, Conn.

Presented before the Sixth Annual Conference of the Instrument Society of America, at Houston, Texas, Sept. 10-14, 1951.

struments which are useful for measurement indication, transmission, and as control component "building blocks" for application in coordinated control systems.

In order to further describe the design and performance of the modified Kelvin balance as an electro mechanical transducer, we have found it useful to present the following comparison with its counterpart in pneumatic powered instruments. For this purpose the comparison will be made with a conventional pneumatic or low pressure air transmitter. Referring to the pneumatic transmitter illustrated diagramatically in Fig. 2, a mechanical input element applies motion through a gauge movement shaft 6 and arm 7 to the link 4. A change in the position

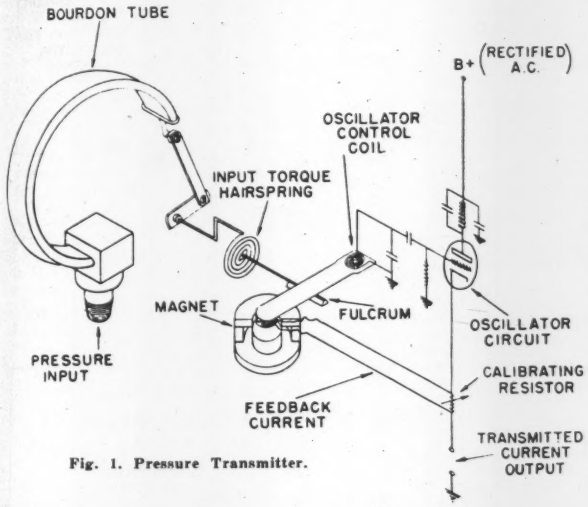

Fig. 1. Pressure Transmitter.

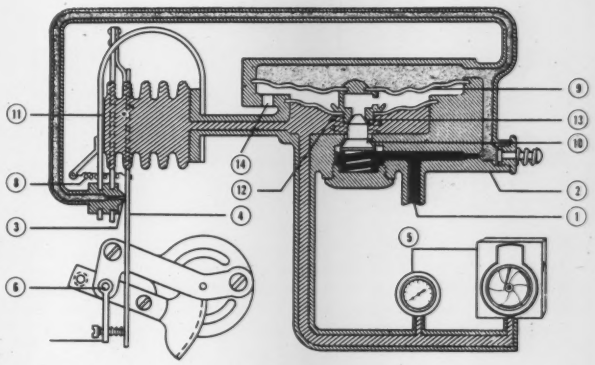

Fig. 2. Pneumatic Transmitter

of this link varies the orifice opening at 3 to change the pressure in the upper chamber of the amplifying relay, and causing motion of the diaphragm 9. Motion of the diaphragm 9 permits air to enter or leave the lower chamber of the amplifying relay to raise or lower the transmitted air pressure. Transmitted air pressure also passes to bellows 11, which repositions the orifice to regulate the output air to the correct value called for by the position of the link 4.

In the electro mechanical transmitter incorporating the modified Kelvin balance, Fig. 3, the motion of the mechanical element or Bourdon tube operates through a gauge linkage and movement to apply a torque to beam 10 through the action of the spring 9. Motion of the beam 10 is equivalent to the link 4 of the pneumatic transmitter. By its effect on the oscillator circuit 2, the motion varies the resistance in the electronic amplifier. Circuit 2 is equivalent to the orifice 3 and the electronic amplifier is equivalent to the air relay of the pneumatic transmitter. Changes in the resistance of the electronic amplifier vary the direct current output of the transmitter. The output is measured by the circuit 6 and the coil 7. Coil 7 is attached to the beam 8 which suspends the coil in a high intensity permanent magnet field. Direct current flowing in the coil produces a force which acts in opposition to the torque of spring 9. The action of the measuring coil 7 is equivalent to that of the bellows 11 and it serves to regulate the output signal proportional to the mechanical input to the beam. In the electro mechanical instrument electric power applied at 1 is equivalent to a source of air pressure applied at 1 of the respective pneumatic transmission systems.

The purpose of presenting this comparison of the operation between transmission systems of the self regulating type is to emphasize the fact that the type of performance applied so successfully in pneumatic control is also available in this type of electrical system. The comparison is also presented to show why each element of the electrical system is necessary in order to achieve performance which is equal in accuracy to accepted standards in pneumatic control.

The specific electro mechanical transducer described in the foregoing comparison is useful for converting mechanical motion into a proportional electric signal. An important application would be for converting the motion of the pressure measuring Bourdon tube to an electrical signal for remote indication or control. Another application would be in connection with mechanical temperature measuring elements which produce motion proportional to temperature. However, the utility of the structure is not limited to unidirectional transducing since the basic structure is adaptable to receiving an electrical input signal for conversion to mechanical work output.

In order to convert an electrical signal into a mechanical output accurately proportional to the input, an electro mechanical amplifier or relay must be inserted in the system. If the value of the electrical signal to be transduced is large enough, the Kelvin balance may be used directly in combination with an air orifice to initiate the measuring operation. The change in pressure at the air orifice is amplified with a pneumatic relay to deliver a change in pressure. The output pressure can be held to an accurate proportion of the electrical input signal with a conventional pressure measuring bellows follow-up system. Motion of the bellows is linked to the loading spring of the balance to produce a counter force to the electrical input. If the electrical input signal is not large enough to operate a variable orifice directly through the balance beam, the electronic amplifier can be inserted in the system to boost the power for the transducing operation. Fig. 4 illustrates schematically how this is accomplished. In this instrument the electro pneumatic proportioning is initiated with a solenoid actuated air valve.

We have now shown how a pressure signal can be converted into a proportional direct current electrical signal. We have also shown how the direct current electrical signal can be transduced accurately to proportional signal in air pressure. In each case the electro mechanical balance serves to make a direct comparison between electrical measurement and mechanical measurement. In these feedback instruments, the amplifying components such as electron tubes, pneumatic relays or proportioning solenoid valves do not have to be precision measuring elements, since errors in the performance of the amplifiers are nullified by the feedback action. The action of the galvanometer balance places these instruments in the category of self regulated or null balance measuring devices.

It is the self regulating or null balance action of the galvanometer balance which overcomes the effects of line voltage variation, electron tube aging, changes in line resistances or differences in electron tube characteristics. Another factor in the performance of precision measuring instruments is the effect of ambient temperature changes. The straight line performance of the galvanometer balance simplifies the problem of dealing

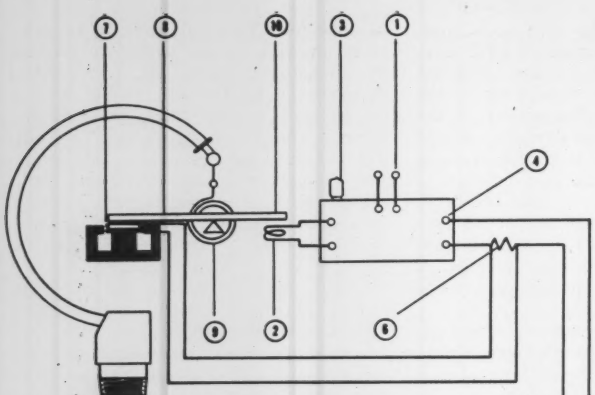

Fig. 3. Electromechanical Transmitter.

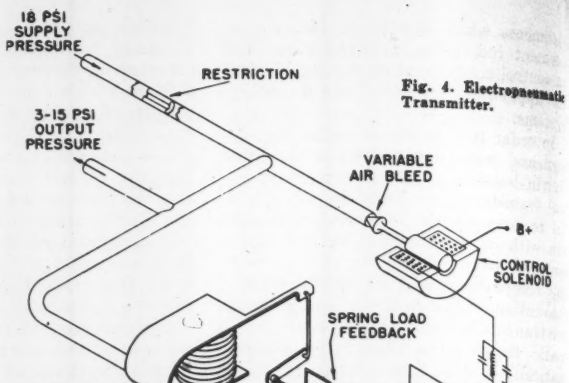

Fig. 4. Electropneumatic Transmitter.

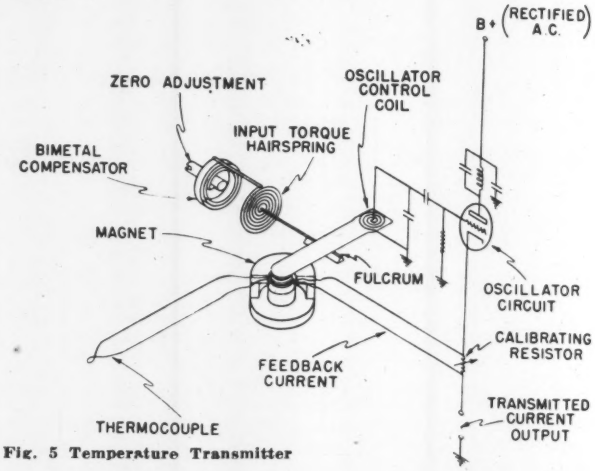

Fig. 5 Temperature Transmitter

with this type of error. Changes in the modulus of measuring springs can be compensated through selection of calibrating resistors with requisite temperature resistance coefficients.

To describe an indicator incorporating this measuring system, we should refer again to the electro pneumatic transducer. By substituting a solenoid acuator responsive to the output of the electronic amplifier, it is possible to drive the recorder for electric indicating or to position the pen arm for electric recording. Again to insure accuracy of the indicated or recorded values, the pointer or pen is linked to the calibrated spring of the balance. This mechanical feedback applies a counter force to the measuring balance to insure accurate positioning of the pointer in terms of the force produced by the electrical input signal. Any unbalance between the electrical input and the feedback signal would be detected by the electronic amplifier to apply the corrective power to the actuating solenoid.

A further application of this measuring system is to simple direct current amplification. In D.C. amplifying the system serves as a proportioning direct current relay. The balance structure can be varied slightly by applying two electrical measuring coils to the beam. One coil serves for measuring the input, the second measures the output and serves as the feedback link. The galvanometer again regulates the output current to maintain a balance with the measured input. The mechanical loading spring now becomes useful for zeroing or preloading the galvanometer for range suppression.

A typical application of the D.C. amplifying system is shown in Fig. 5. This schematic presents the amplifier as a temperature transmitter having a thermocouple input element. In this illustration the mechanical loading spring not only serves for zeroing and suppressing the range of the transmitter, but it is also the means for applying thermocouple cold junction compensation. The temperature of the thermocouple junction located in the instrument case is measured with a bimetallic element which rotates the calibrating spring to compensate for ambient temperature variations.

The D.C. amplifier is also useful as a repeater station in long transmission circuits and as a simple proportioning controller for applications not requiring automatic reset.

Another useful form of the D.C. amplifier is for contact operation. In this instrument a manual setting pointer is applied to the calibrated loading spring of the balance. It is possible thereby to set the pointer against a calibrated scale to select the operating signal for the contacting relay. Furthermore, the electrical feedback from the electronic circuit may be adjusted to vary the operating differential for the contacting relay.

Now reviewing the instruments which have been described, it is seen that they include or can be related to nearly all of the basic measuring requirements for process industry. Furthermore, the objective of a standardized approach to the measurement problems has been introduced. In the detail application of this measurement approach there are many steps yet to be taken. However, the pattern for standardizing the approach is indicated. Through this approach it is proposed to establish instrumentation systems constructed with standardized components for measurement, transmission, indication, controlling and signalling. These instruments to be constructed with the same basic components would be interchangeable or readily modified in the field in accordance with changes in process operations and requirements.

In a program directed towards standardization, compromise is an accepted requirement and it is not intended to imply that many specialized measurement problems will not require highly specialized or application

engineered measuring and control equipment. The systems proposed here are simply one approach toward the objectives for more rapid signal measurement and transmission with compatibility to existing instrumentation and opportunities for increased standardization.

Control Valve Symposium

The Essex House Hotel in Newark, New Jersey, on April 1st, will be the site of a Symposium covering "The Use and Application of Control Valves," sponsored by the New Jersey Section of ISA.

The Symposium will be held in three sessions—the first starting at 9:30 A.M.; the second, at 2:00 P.M.; and the third at 8:00 P.M. Preprints of all papers (listed below) will be available. Registration will start at 9:00 A.M. and continue throughout the day.

"The Selection and Sizing of Control Valves," Otto Kneisel, Hammel-Dahl Co.

"Valve Rangebility," R. A. Rockwell, Mason-Neilan Co.

"Correlation of Cv Factors," G. F. Brockett, Fisher Governor Co.

"Flow of Viscous Liquids Through Control Valves," Dr. D. P. Eckman, Consultant, Conoflow Corp.

"Control-valve Characteristics and Their Effects on Flow Control," Russell Milham, The Foxboro Co.

"Engineering the Three-way Control Valve," R. L. Patten,* Gulf Oil Corp.

*Written in collaboration with the late Mr. J. A. Pellettere.

Cleveland Committee Meeting

At the recent meeting in the Hollenden Hotel, Cleveland, preliminary plans for the Seventh National Instrument Conference and Exhibit were discussed. Three meetings were held:

10:00 A.M. National ISA Meetings Committee
1:00 P.M. Cooperating Societies Committee
3:00 P.M. Cleveland Host Committee

Below is a photograph of the Meetings Committee meeting. Left to right: R. E. Tozier, Chairman Technical Advisory Committee; G. D. Carnegie, Chairman Meetings Properties Committee; Fred Lennon, Chairman Cleveland General Committee; Robert Newton, Vice-Chairman Cleveland General Committee and Chairman Employment Register Committee; William Uhl, Chairman Publicity Committee; I. Warshowsky; D. B. MacDougall, ASME Staff; Dr. W. G. Brombacher, Chairman Industrial Instruments and Regulators Division, ASME; P. V. Jones, Manager ISA; M. D. Shriver, ISA National Meetings Committee; Richard Rimbach, Exhibit Manager; R. R. Proctor, ISA National Meetings Committee; and E. S. Lee, Chairman ISA Intersociety Relations Committee.

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SALES ENGINEERS. Sales Engineers for large industrial instrument manufacturer. Prefer Mechanical, Electrical or Chemical Engineers with few years industrial experience. Fine opportunity for young engineers with sales aptitude to connect with one of the fastest growing industrial instrument companies in the United States. Locations: Houston, Texas, and Los Angeles, California. In addition to above we desire services of Application Engineers who will be located at factory in New England. Exceptional opportunities. Box 639.

SALES ENGINEER. Graduate Engineer (Ch.E. Preferred) 25-35, for application engineering leading to outside sales or sales management. Direct sales experience not required. Salary plus profit-sharing. A real opportunity with young, aggressive process equipment manufacturer—already No. 1 in field. Ideal working conditions in new Suburban Philadelphia Office. Box 640.

INSTRUMENT TECHNICIAN. Major pharmaceutical manufacturing company has challenging position available for man interested in the selection, application, installation, testing and maintenance of electrical, pneumatic, mechanical and other measuring and control instruments used in a variety of chemical and biological processing equipment. Previous experience necessary. Salary commensurate with qualifications. Location Michigan. Box 641.

INSTRUMENT MECHANICS. Experienced instrument mechanics for work in chemical plants. The work is inspecting, testing, repairing, adjusting, and calibrating service instruments, including actuating connections and control equipment. Instruments are electrical, mechanical, pneumatic, hydraulic, thermal, or any combination of these. Salary is $4075 per year for 40-hour week. Liberal vacation leave, sick leave, and retirement benefits. Location Alabama. Box 642.

Papers for 1952

In arranging the technical program for the 1952 Conference, short contributed papers are solicited from all members. Within the limits of program time, any member may be allowed ten to fifteen minutes to present his contribution. Only the title and an abstract of 200 words or less need be submitted for these papers and they can be submitted up to July 1. However, it is hoped that authors will submit manuscripts also, so that their papers may be considered for publication in the Journal of the ISA. Longer papers, to be considered by the Editorial Committee, should be submitted at once, to allow time for editorial review and preprinting.

ANNUAL BANQUET OF THE NEW YORK SECTION, held during the Fifth Regional Conference on "Power Plant Instrumentation," Hotel Statler, February 7-8, 1952. Guest speaker at the banquet was Rear Admiral William S. Maxwell, U.S.N.(Ret.), Deputy Director, Bureau of Smoke Control, Department of Housing, City of New York. At the head table from left to right Richard Rimbach, Norman J. Cherry, Admiral Maxwell, Charles Haggerty, and Leopold Van Blerkom.

Cleveland Exhibit Space Exceeds Previous High

Six months before the opening date, the amount of booth space reserved at the Seventh National Instrument Conference and Exhibit, Cleveland, Ohio equals the total amount of booth space occupied at the largest previous Show —the Sixth National Instrument Exhibit, Houston, Texas.

Last November, 165 booths were laid out in the Arena of the Cleveland Public Auditorium. By the end of December this space was exhausted and 108 additional booths were then laid out in the Main Exhibition Hall. At this time 40 of these booths have been reserved, giving a total of 205 booths reserved by 131 exhibitors.

Below is a resume of the previous exhibits:

Date	*Location*	*No. Exhibitors**	*No. Booths**	*Exhibit Space Sq. Ft.*
1946	Pittsburgh	92	120	10,291
1947	Chicago	126	154	16,194
1948	Philadelphia	147	200	22,022
1949	St. Louis	133	182	21,930
1950	Buffalo	135	191	18,160
1951	Houston	133	212	22,240
1952	Cleveland	131	205	22,260

*Note: Booth space allocated free to Government Agencies, not included.

There are only 68 booths to be disposed of in the next six months and of these approximately 20 booths will be alloted to the Cooperating Societies and Government Bureaus. The possibility of disposing of the remaining available booths is very good in which case the Cleveland Exhibit will be 20 percent larger than any previous Exhibit.

With the increased activity on the part of the technical committees of the Instrument Society of America and the cooperating societies, a record breaking attendance is expected.

A list of the companies, which have contracted for space, follows:

Acragage Corp.
American Meter Co.
Ambos Jones Co.
Anderson & Sons, Inc.
Annin Co.
Askania Regulator Co.
Assembly Products, Inc.
Associated Research, Inc.
Automatic Electric Sales Corp.
Automatic Temperature Control Co.
Bacharach Industrial Instrument Co.
Baird Associates, Inc.
Baker Co.
Barton Instrument Corp.
Beckman Instruments, Inc.
James G. Biddle Co.
J. Bishop & Co.
Black, Sivalls & Bryson, Inc.
Bowser, Inc.
Brooks Rotameter Co.
Brush Development Co.
Buffalo Meter Co.
Burgess Battery Co.
Burling Instrument Co.
Cameron Iron Works, Inc.
Carboloy Dept., GE
Century Geophysical Corp.
John Chatillon & Sons
Cole Instrument Co.
Conoflow Corp.
Consolidated Engineering Corp.
Continental Equipment Co.
Cook Electric Co.
R. W. Cramer Co.
Crawford Fitting Co.
Daniel Orifice Fitting Co.
Daven Co.
Davis Instruments
DeZurik Shower Co.
F. W. Dwyer
Eagle Signal Corp.
Edin Co.
Thos. A. Edison, Inc.
Esterline Angus Co.
Farris Engineering Co.
Fenwal, Inc.
Fielden Instrument Corp.
Fischer & Porter Co.
Fisher Governor Co.
Foster Engineering Co.
Fulton Sylphon Div., Robertshaw-Fulton Control Co.
General Electric Co.
General Mills, Inc.
Gow-Mac Instrument Co.
Hammel-Dahl Co.
Hankison Corp.
A. W. Haydon Co.
Hays Corp.
Helicoid Gage Div., American Chain & Cable Co.
Herschede Hall Clock Co.
Hickok Electrical Instrument Co.
Hills McCanna Co.
Holtzer Cabot Div., National Pneumatic Co.
Imperial Brass Mfg. Co.
Industrial Instrument Corp.
Industrial Instruments, Inc.
Industrial Laboratories Publishing Co.
Industrial Pyrometer & Supply Co.
Instruments Pub. Co.
J-B-T Instruments, Inc.
Jerguson Gage & Valve Co.
C. M. Kemp Mfg. Co.
Kieley & Mueller, Inc.
Lapp Insulator Co.
Leslie Co.
Librascope Inc.
Lord Mfg. Co.
Magnetrol, Inc.
Marine & Industrial Products Co.
Mason-Neilan Regulator Co.
McAlear Mfg. Co.
Meriam Instrument Co.
Metrotype Corp.
Midwestern Geophysical Co.
Milton Roy Co.
Mine Safety Appliances Co.
Minneapolis-Honeywell Regulator Co., Valve Products
Mittleman Electronics Div., Century America Corp.
Samuel Moore & Co.
Nash Engineering Co.
National Spectrographic Labs, Inc.
New Hermes Engraving Machine Corp.
North American Philips Co.
Palmer Thermometers, Inc.
Panellit, Inc.
Parker Appliance Co.
Penbethy Injector Co.
Perkin-Elmer Corp.
Permutit Co.
Photoswitch, Inc.
Physicists Research Co.
Potter Aeronautical Co.
Potter and Brumfield
Production Instrument Co.
Proportioneers, Inc.
Research Control Co.
Rockwell Mfg. Co.
R-S Products Corp.
Sanborn Co.
Sarco Co.
Sola Catalytic Co.
Sorensen and Co.
Southwestern Industrial Electronics Co.
Spence Engineering Co.
Standard Electric Time Co.
Herman H. Sticht Co.
Superior Electric Co.
Superior Tube Co.
Surprenant Mfg. Co.
Swartwout Co.
Technical Sales Corp.
Telechron Dept., GE
Uehling Instrument Co.
Vapor Recovery Systems Co.
Veeder-Root, Inc.
Victoreen Instrument Co.
Wallace & Tiernan Products, Inc.
Warwick Products Co.
Weatherhead Co.
W. M. Welch Mfg. Co.
Wheelco Instruments Co.

Your Hotel Reservation -- Cleveland

If you plan to attend the Seventh National Instrument Conference and Exhibit in Cleveland, Ohio, September 8 to 12, 1952—*make your hotel reservations at the earliest convenient date.*

The room situation will be critical in September, and an early reservation made now will save you considerable time and trouble later on. Those who failed to make early reservations for previous annual meetings are well aware of the annoyance of last-minute accommodation making.

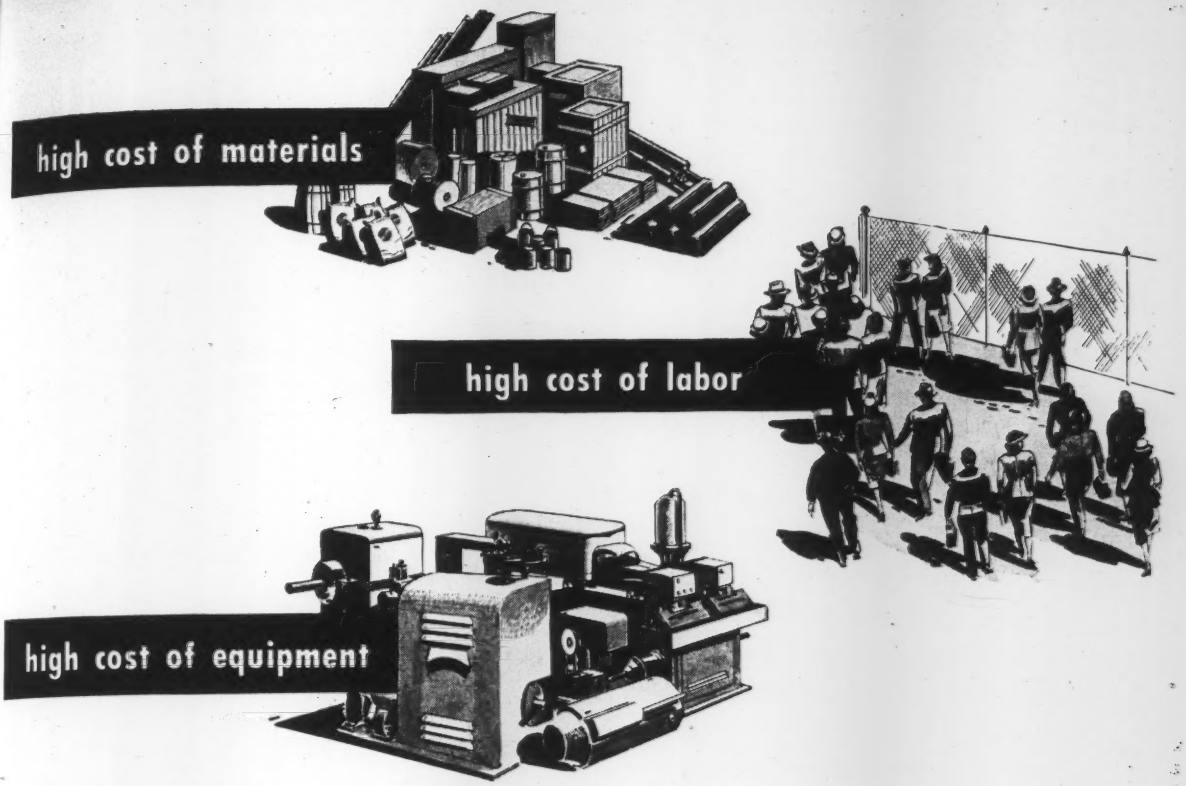
Make your reservations now.

Below is a list of the hotels which have committed rooms for the period of the Conference and Exhibit. The approximate distance from the Auditorium and the price range for the various types of accommodations are given also.

Please make your reservations directly with the hotel of your choice, advising the hotel that you intend to visit the Instrument Conference and Exhibit and stating the date and approximate time of your arrival, the number of days you expect to remain, and the type of accommodations required.

Hotel	*Location*	*From Auditorium*	*Single*	*Double*	*Twin Bedded*	*Suites*
Alcazar	Surrey & Derbyshire Rds.	5 miles	$6.50 to 8	$8.50 to 10	$8.50 to 12	$12 to 20
Allerton	1802 E. 13th St.	8 Blocks	4 to 7	6.50 to 9	7 to 10	12 to 20
Auditorium	1315 E. 6th St.	1 Block	4 to 7	6 to 9	8.50 to 9.50	14 to 20
Belmont	3844 Euclid Ave.	1½ Miles	3.25 to 3.50	5 to 5.75	4.25 to 6.25	
Bolton Square	8907 Carnegie Ave.	3½ Miles	3.50 to 5	5.50 to 7	6 to 7.50	8 to 25
Carter	Prospect & E. 9th St.	7 Blocks	4 to 7.50	6 to 10	8 to 12	20 to 40
Cleveland	Public Square	4 Blocks	4.50 to 8	7 to 10	10 to 15	30—2 rms. 32—3 rms.
Commodore	Euclid & Ford Drive	4 Miles	6 to 7.50	8 to 10	8.50 to 12	12 to 20
Hollenden	610 Superior Ave.	3 Blocks	4 to 8	6 to 12	8 to 15	15 to 22—2 rms. 26 up—3 rms.
Lake Shore	12506 Edgewater Drive	4 Miles	5 up	8 up	8 up	10 up
New Amsterdam	Euclid & E. 22nd St.	1 Mile	3 to 4	5.50 to 6	6 to 7	7 up
Olmsted	Superior & E. 9th St.	4 Blocks	3.75 to 6	6.50 to 9	7.50 to 9.50	10 to 15
Park Lane Villa	10510 Park Lane	7 Miles	5.00	6.00	7 to 8	
Quad Hall	7500 Euclid	3 Miles	3 to 6		6 to 10	10 to 18
St. Regis	8205 Euclid Ave.	3½ Miles	3 to 4	5 to 8	5 to 8	8 to 12
Sovereign	1575 East Blvd.	4 Miles	5 to 6	6 to 10	6 to 12	
Statler	Euclid & E. 12th St.	6 Blocks	4.50 to 9	7.50 to 10.50	9 to 14	18 to 26
Stockbridge	3228 Euclid Ave.	1½ Miles	3.00	5.00	6.00	
Tudor Arms	10660 Carnegie Ave.	4 Miles	4.50 up		7 up	14 up
Wade Park Manor	E. 107th & Park Lane	4 Miles	5.50 up	7.50 up	8.50 up	10 up
Westlake	Blount Rd. Rickey River	7 Miles	5 to 6	8 to 9	9.00	10 to 15

These rates are subject to change at any time.



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Reprinted from *Dun's Review*, December 1951

INSTRUMENTS ON THE MARCH

New Principles. Applications. Non-commercial Developments

Network Calculator

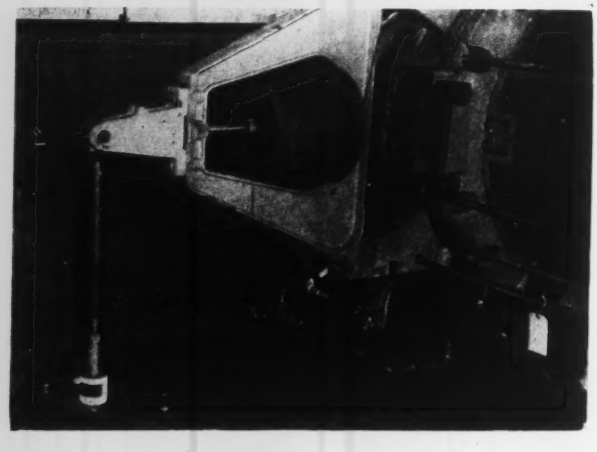
E. PITTSBURGH, Pa.—The a-c. network calculator at the East Pittsburgh plant of Westinghouse Electric Corporation was in almost constant use during 1951 by utility customers. The picture shows Engineers from the Duquesne Light Company working with Westinghouse engineers in making a complex system study that would require man-

years of hand calculation. Electrical "analog" representation of a utility system on the calculator makes it possible to impose any conditions desired and study the effects throughout the system. Results are recorded on the plotting board (foreground), metering is controlled from the control desk (behind plotting board), and generator and system characteristics are set on the board (right and background). Westinghouse has built 19 such calculators and has two on order.

Force Measurement

WOODRIDGE, N. J.—Dynamometer loads are weighed by an electronic system recently adopted at the Woodridge, N. J., plant of Wright Aeronautical Corporation. SR-4 load cells are shown at the left under the column linked to the arm of a G.E. Cradle-type dynamometer of 3000-hp. capacity. The dynamometer is being used for full-scale tests of aircraft reciprocating engines.

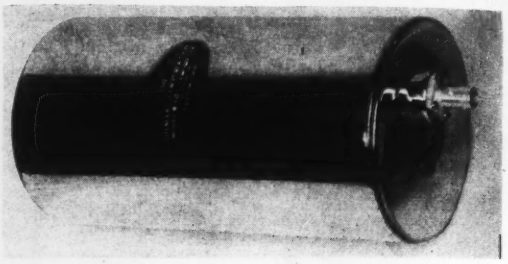
SR-4 load cells are essentially steel columns or rods to which SR-4 resistance wire strain gages are bonded. Strains



in the column (either stretch or compression) affect the electrical resistance of the strain gages. Electronic circuits of an indicator or recorder automatically convert resistance changes into units of torque or thrust.

Radioactive-energy Transducer

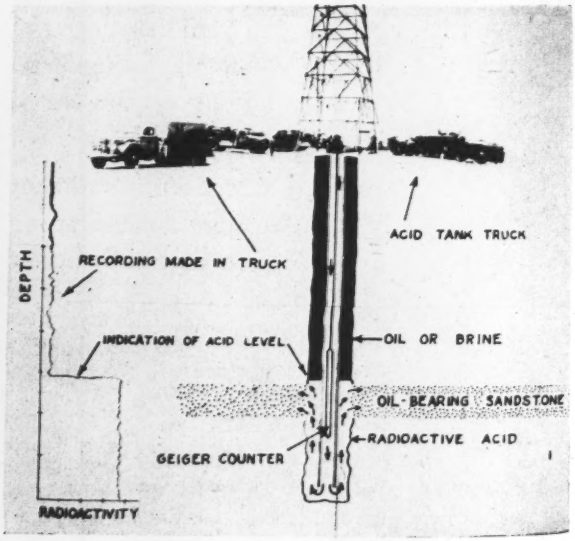
CINCINNATI, OHIO.—New transducer made by Ohmart Corporation, Cincinnati, Ohio converts radioactive energy to electric energy without use of high-voltage power sup-



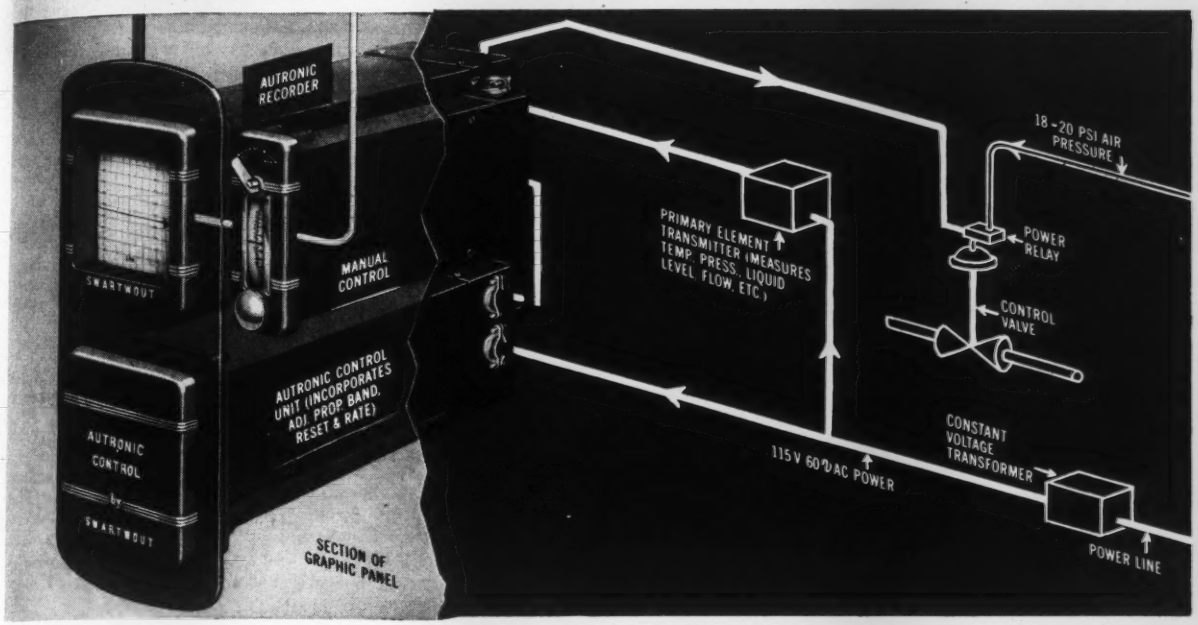
ply. Pickup cell is constructed of two dissimilar-metal electrodes separated by a filling gas. When gas is ionized by radiation, the positive ions are attracted to the noble electrode, and the electrons are attracted to the active electrode, owing to the chemical assymetry of the electrodes. The result is an electric current—without high-voltage supplies.

Radioactive Isotopes in Industry

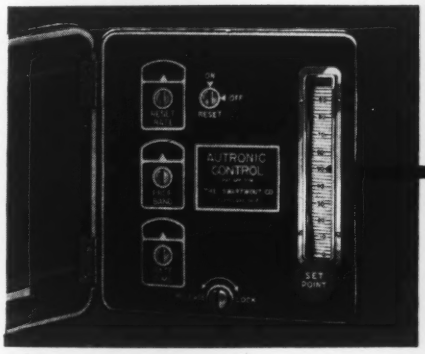
DETROIT, Mich.—One of the first major industrial applications of radioactive isotopes produced at the atomic energy plants of Oak Ridge, Tennessee, has been revealed by Radioactive Products, Inc., Detroit, Michigan. This new application is increasing oil production by a new method of controlling and evaluating oil-well acidizing. The re-



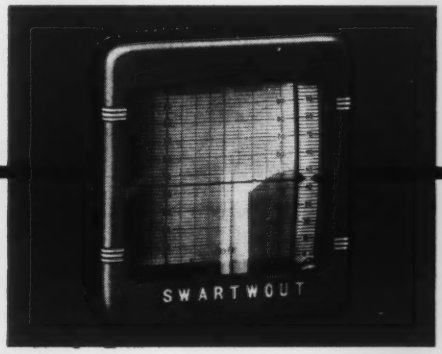
Miniature all-electronic system for instantaneous measurement and control of process variables...


AUTRONIC RECORDER
SWARTWOUT
MANUAL CONTROL
AUTRONIC CONTROL UNIT (INCORPORATES ADJ. PROP. BAND, RESET & RATE)
AUTRONIC CONTROL by SWARTWOUT
SECTION OF GRAPHIC PANEL
PRIMARY ELEMENT TRANSMITTER (MEASURES TEMP, PRESS., LIQUID LEVEL, FLOW, ETC.)
18-20 PSI AIR PRESSURE
POWER RELAY
CONTROL VALVE
CONSTANT VOLTAGE TRANSFORMER
115 V 60 CYC AC POWER
POWER LINE

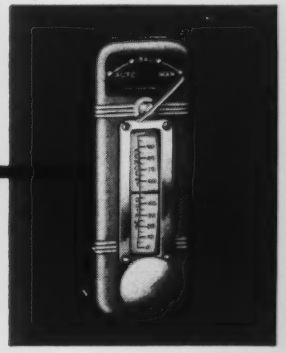
1 Regardless how fast a pneumatic or electro-mechanical system may function, it cannot compare with the *instantaneous, all-electronic* response of the Swartwout Autronic Control System. Here's why. Since transmission of information throughout the system is by *electrical means only*, there is no mechanical motion . . . no slide wires, boosters or motors to initiate control action . . . no control air lines from primary element or to final element. Hence the Autronic Control System *spans distance between primary and final elements without interval* —for closer, more accurate control. A-4940



2 **AUTRONIC CONTROLLER**, heart of the system, has no moving parts. Proportion, reset and rate-action adjustments; with or without built-in set-point adjustment. Extremely compact, plug-in type units are interchangeable; can be used direct or reverse-acting.



3 **AUTRONIC RECORDER** operates without slide wires or other contacting mechanisms. Electronically controlled pen gives true linear trace. Unit holds 1-month supply of standard 3-inch linear or square root chart paper. Set-point adjustment optional with Autronic Recorder.



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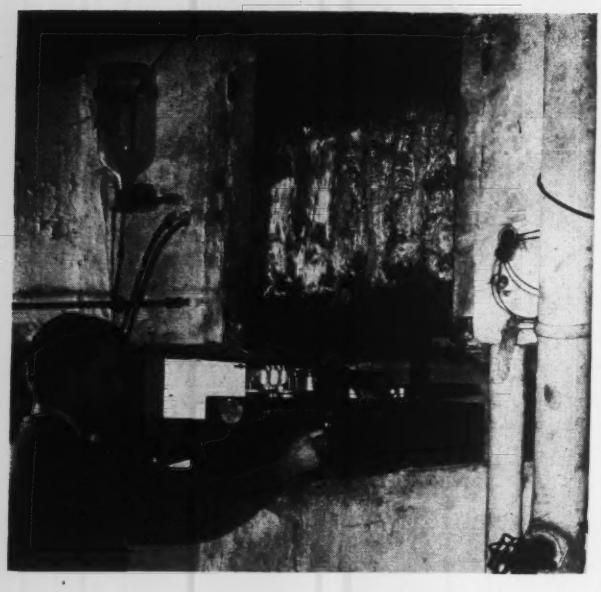

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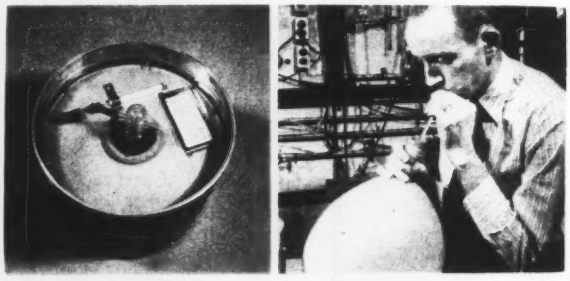
Radon Measurement and Control

WASHINGTON, D. C.—To protect the health of personnel engaged in work involving the handling or processing of radium, the National Bureau of Standards maintains careful check, throughout the United States, over the quantity of radium ingested by such personnel and over the quantity or radon present in their working areas. According to Technical Report 1482, the breath of these workers or the air in the work room is sampled periodically



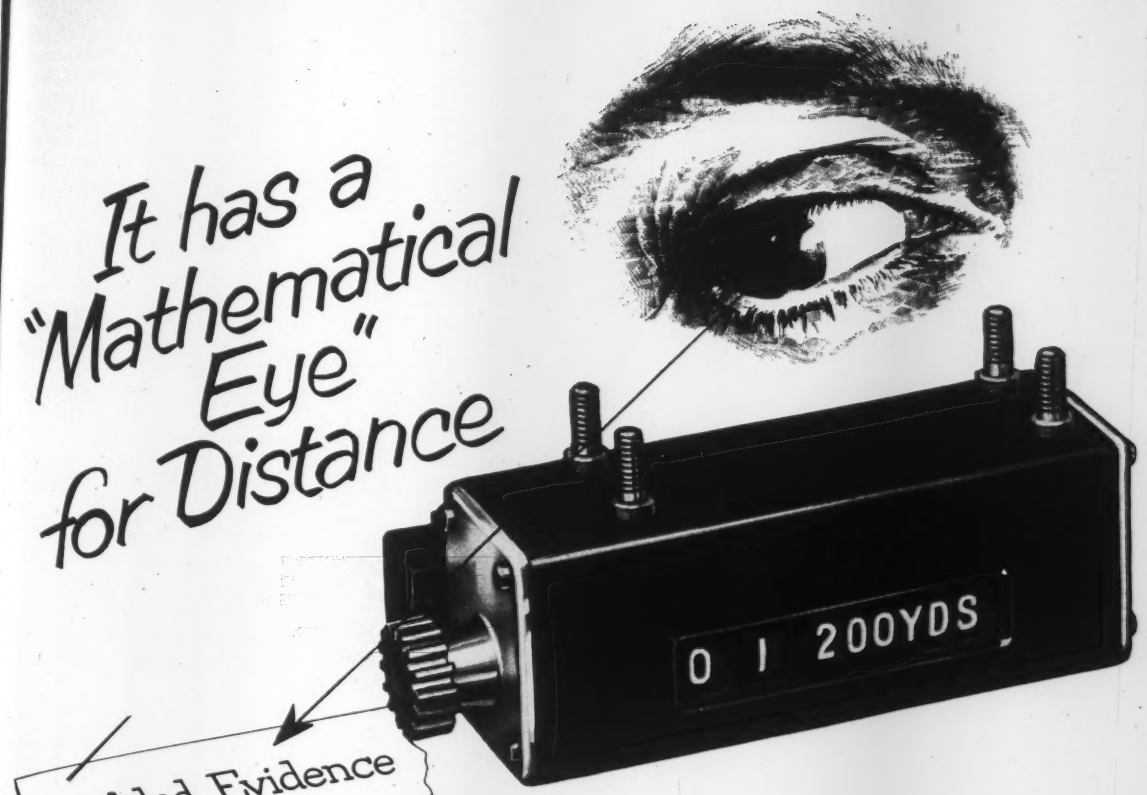
and is measured for its content of radon, which is the gas produced by radioactive disintegration of radium. This analysis reveals the amount of radioactivity present and provides the basis for the establishment and maintenance of proper safety measures.

For uniformity, sampling flasks for all air samples are supplied by the National Bureau of Standards. These Pyrex flasks are evacuated in the laboratory and sent out, upon request, in aluminum shipping containers packed with foam rubber. After being filled with room or mine air or exhaled air, the flasks are returned for determination of radon content. Work-room air samples are collected by opening the stopcocks on the evacuated flasks so that the air flows in through a filter. Breath samples are obtained by inflating a balloon and then transferring the exhaled air into the evacuated flask through its stopcock.

Torquemeter Tests Centrifugal Pumps

MILWAUKEE, Wis.—Determination of horsepower input of centrifugal pumps has been simplified by electric strain-type torque meters, plus speed-measuring equipment of a new type. Time and labor of testing pumps are expected to be cut by 60 percent in the laboratory of Allis-Chalmers Manufacturing Company, where the new equipment is installed.

Torque is measured by a Baldwin SR-4 torquemeter,



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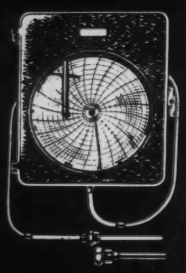

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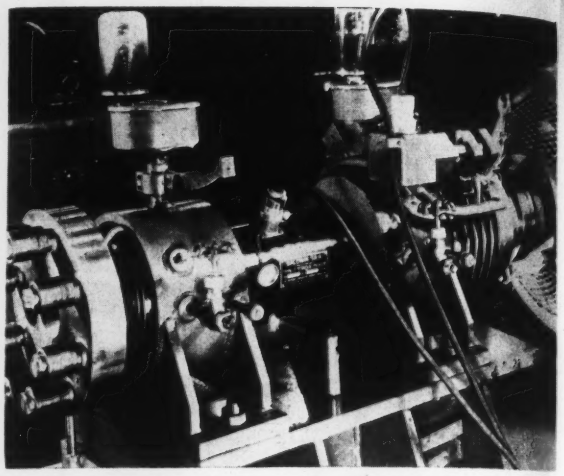


which uses SR-4 resistance-wire strain-gages bonded to a reduced section of a special alloy-steel shaft at 45 deg. with the longitudinal axis. In this position the gages respond to the maximum torsional strains resulting from applied torque. Gages are connected to form a Wheatstone bridge in which bending and thrust stresses are cancelled, but torsional stresses are made cumulative. The stresses cause bridge unbalance. Torque, drive-shaft speed, pump discharge pressure, and inlet pressure are recorded automatically. The illustration shows the torquemeter on a 50-hp. test pedestal for centrifugal pumps.

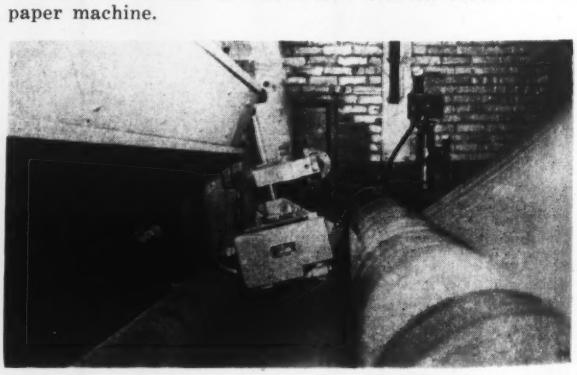
Absolute Viscosity of Water

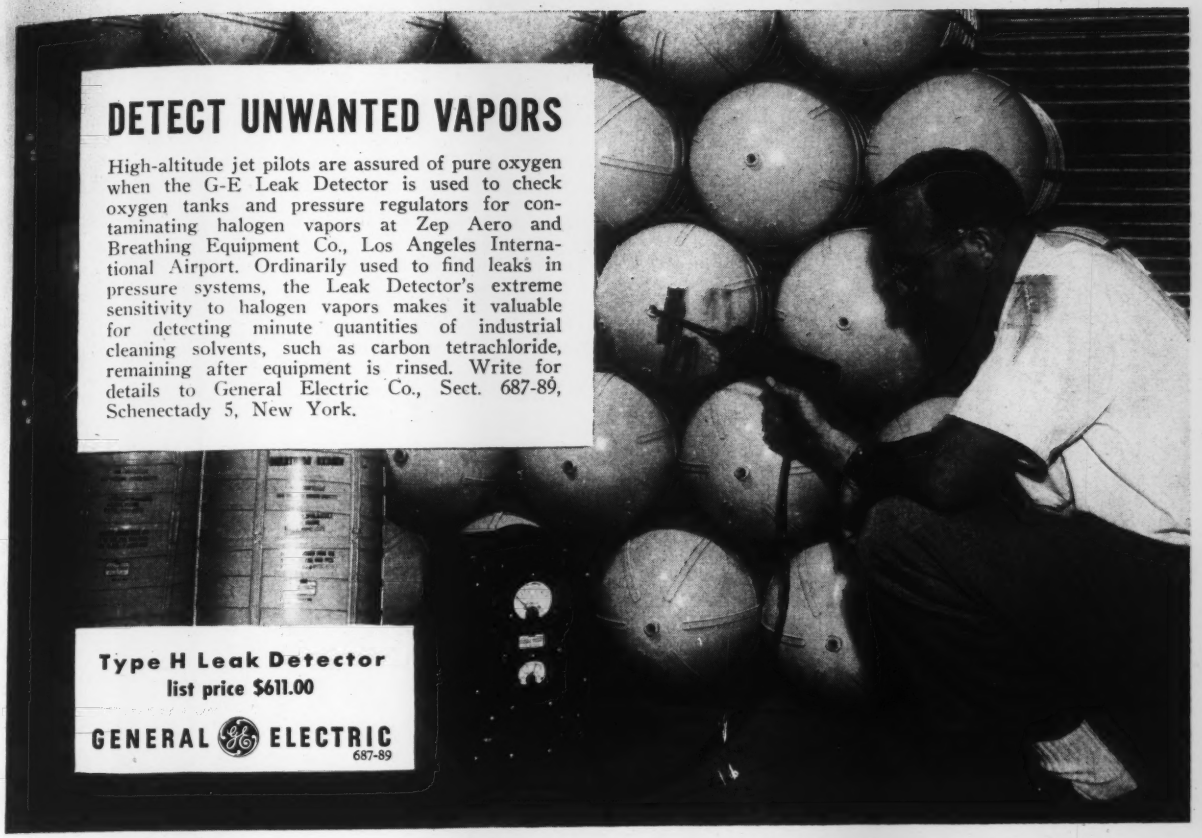
WASHINGTON, D. C.—A determination of the absolute viscosity of water at 20 deg. C. with greater accuracy than ever before realized has recently been completed by J. F. Swindells of the National Bureau of Standards, according to Technical Report 1621. The new value is 0.01002 poise (dyne-seconds per square cm.) as compared with 0.01005 poise, which has been generally accepted up to the present time. The absolute viscosity of water serves almost universally as the standard to which the viscosities of all other liquids are referred.

Beginning July 1, 1952, the Bureau will use the new value as the primary standard for calibrating viscometers and for evaluating secondary standards which are issued as viscometer calibrating liquids. It is recommended that, in so far as possible, this change be adopted generally at the same time.

Tension Control

SPRING GROVE, Pa.—A G-E paper tensiometer installed between first calender and second calender at P. H. Glatfelter Company, Spring Grove, Pa., gives close control of paper tension. The tensiometer is mounted on an adjustable lead screw to take care of different pass lines to second calender. It is used for automatic tension control on the paper machine.





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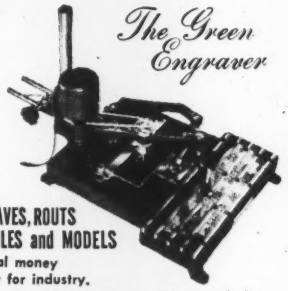

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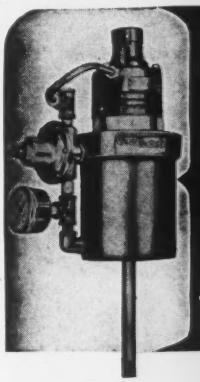

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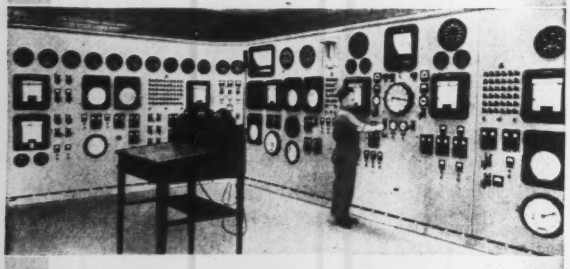

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Optimalizing Control

Continued from page 327

line passing through the four plots. Within the time period from the origin to this vertical dashed line, the control system was operating with the intake manifold pressure used as the controlled input. This fact is identified at the top of plot (a). Within the time period from the vertical dashed line to the end of the plots, the system was operating with the ignition timing as the controlled input. The vertical dashed line shows the instant at which the controlled input was changed from air flow to ignition timing.

The optimum output power level was determined by tests made with manual adjustments. This optimum output was used as the reference level for the deviation plot of Fig. 20a. Before the establishment of this optimum level, the engine was allowed to warm up for more than an hour, so that the environmental inputs to the engine reached relatively stable levels, and the optimum output level obtained by manual adjustment became a reliable reference level. After the optimum output power level had been determined, the ignition timing was retarded from the optimum ignition-timing (represented by the horizontal dashed line in Fig. 20c), to produce an output deviation of approximately two percent from optimum power. After this was done, an additional output deviation of five percent of best power was introduced by changing the intake manifold pressure setting from the optimum level (shown by the horizontal dashed line of Fig. 20d. Starting with this initial output deviation, the controller was allowed to begin operation. The curve in Fig. 20d shows that the intake manifold pressure increased from 23 inches of mercury to 28.5 inches of mercury during an interval of about 25 seconds. The manifold pressure caused a corresponding airflow change and an increase in output level, as shown in Fig. 20a.

The recovery time is the time required for the output to reach a level corresponding to a deviation equal to five percent of the initial deviation. As shown in Fig. 20a, the recovery time of the engine with airflow as the controlled input was about 17 seconds.

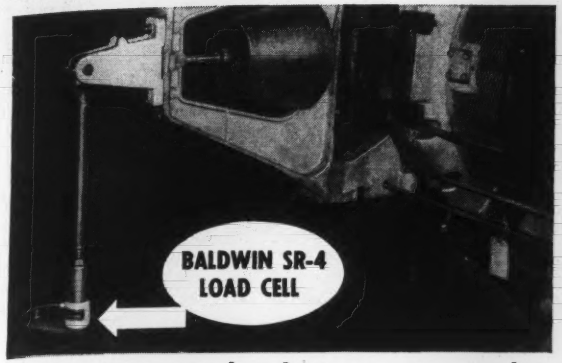
After the recovery time had elapsed, the system exhibited an output hunting period of 13 seconds, as shown in Fig. 20b by the time interval between the two adjacent input-drive reversal points. The input-adjuster-drive selection switch was operated near the third peak of the effective output deviation to change the controlled input from air flow to ignition timing. The variation of ignition timing with time is shown in Fig. 20c.

This plot shows that the ignition-timing adjustment initially happened to be in the wrong direction, which caused a retardation of the ignition timing and in turn caused the output to decrease. This condition was corrected almost immediately by an input-drive reversal, which changed the direction of the ignition-timing adjustment toward a larger angle and thus caused the output to increase. The plots of Fig. 20 show that the controller operation with ignition timing as the controlled input caused the effective output deviation to reach the zero level and then to hold this level within about 1/3 percent of optimum power over the period covered by the plots.

The results shown in Fig. 20, which represent the performance achieved from the experimental controller, are summarized and compared with the design performance in the following table:

	Design Performance	*Actual Performance*
Recovery time	30 sec.	17 sec.
Output hunting period	Longer than 12 sec.	13 sec.
Output hunting loss	1/10% of optimum power	1/9% of optimum power

The table shows that the designed performance for the optimalizing control of a C.F.R. engine was achieved by the experimental test. A C.F.R. engine with its single cylinder can be considered as an operating system with exceptionally high output interference. For this reason it is believed that the satisfactory operation demonstrated by the optimalizing control of this engine can be expected



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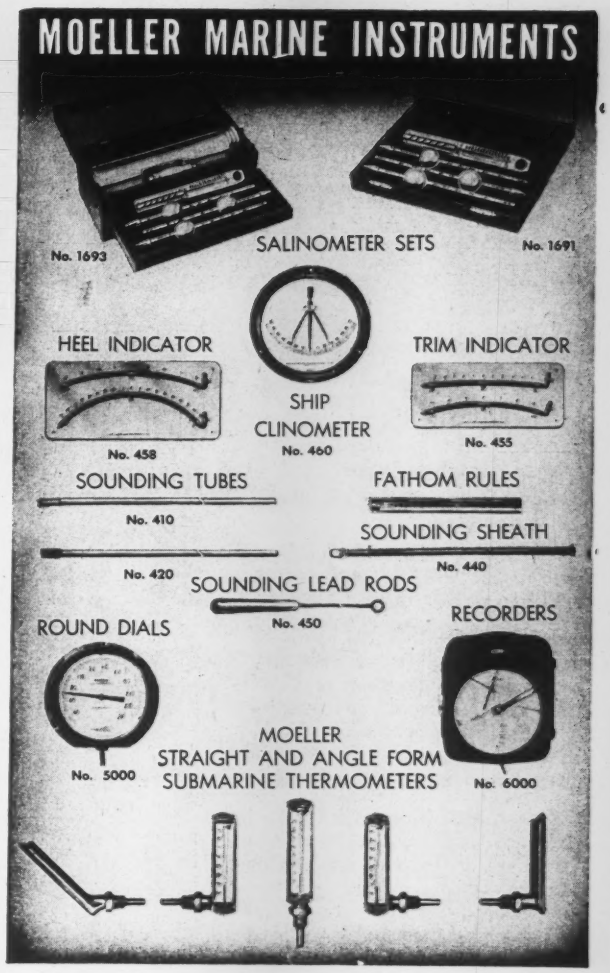

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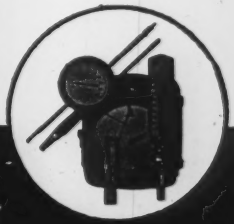

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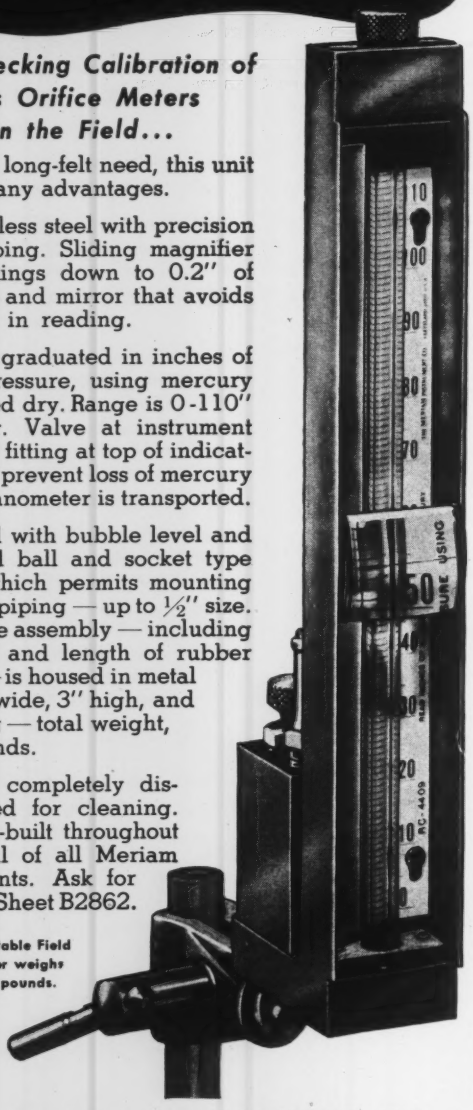

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DISCUSSION

Question: In the optimalizing control system which Dr. Li has presented here, he has shown the use of an engine as his process unit, which is being held to an optimum output by control of one or two variables. In trying to carry this thought over into the process industry, where we will be maintaining an optimum operation of a refinery unit, would the optimalizing-control system have to seek out the optimum point for each of the numerous variables which hold that process unit on stream in making end product? Would it do that in a sequence, or would he propose that the system simultaneously change the variables on this process unit to bring it up to the optimum point? In the latter case I was wondering if thought had been given to how that intelligence to each of the controllers should be kept from getting mixed up and confused.

Y. T. Li: I think your question has been put very intelligently, and this is a very important matter in our optimalizing-control system. In the example using an internal-combustion engine as the controlled system, we took both the intake air flow rate and the ignition timing as two controlled inputs. To separate the effect on the output due to these inputs, we can make adjustment of one of the two inputs alternatively. In the continuous-type optimalizing system described, we can adjust the two inputs simultaneously by using a different test-input frequency for each input. The intelligence to each signal can be separated from each other by suitable filters. For any system with more than two controlled inputs, this same principle applies.

Axel Petersen: I would like to have some specific examples as applied to a chemical plant.

Li: I am sorry that I do not have any specific examples for a chemical plant at the moment. However, we may consider that in some cracking processes, the condition of a certain kind of catalyzer may affect the amount of the output and therefore may be considered as a controlled input. Or, in some big power plants that use coal to produce steam, the coal is transferred to carbon dioxide and at the same time produces heat. This also is a chemical process. In this case, the amount of steam produced may be optimalized by controlling the damper of the chimney.

Oxygen-Plant Instrumentation

Continued from page 323

6. During appropriate parts of the time cycle, the cam and selector switch move in combination to energize the four-way solenoid valve. The solenoid valve causes air flow to the cylinder operator of the valve to produce the desired valve movement.

Instrumentation Complimentary to Control System

In addition to the control instruments, other instruments are required to indicate and record temperatures, pressures, flows, liquid levels, and chemical analyses useful in the interpretation of the performance of the plant. Novel instrumentation is not required for the super-atmospheric temperature service of the process. However, certain features of the instrumentation for the low-temperature service are unique.

It is essential for most efficient operation that low temperatures be measured with an accuracy of 2 deg. F.; even more accurate measurements are desirable. Copper-constantan couples in stainless-steel thermowells and in stainless-steel thermowells with copper tips are adequate for the primary element. A typical arrangement of a couple and stainless-steel well is shown in Fig. 7. The tip of the well has been reduced in mass to increase the response and to minimize the error of temperature measurement. When such a couple is adequately immersed in the cold stream, is opposed by a cold junction maintained at liquid-oxygen temperature, and is read by means of an indicating potentiometer, it is accurate to within one or two degrees F. There is no obvious reason why other methods of measuring temperature, such as resistance thermometers adequately protected from stray currents, should not be equally satisfactory or

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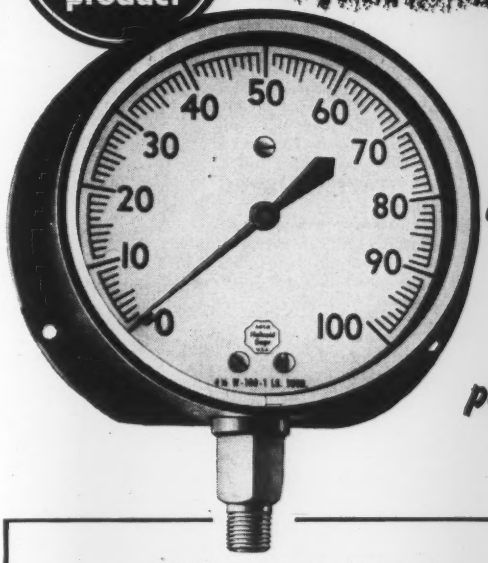

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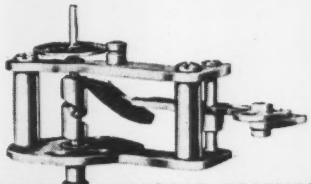

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superior to thermocouples. However, such devices have not yet been tried in HRI plants.

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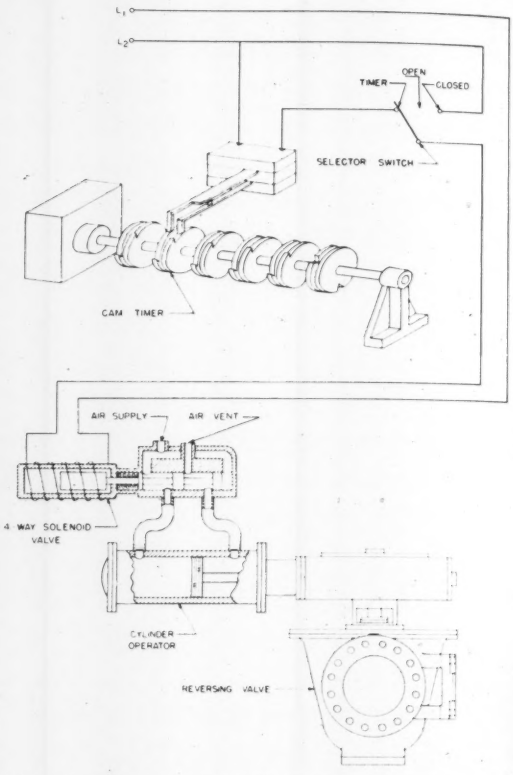

Fig. 6. Arrangement for automatic operation of reversing valves.

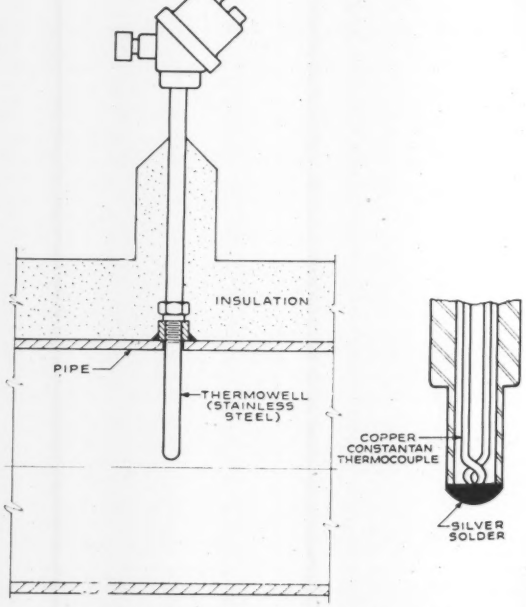

Fig. 7. Low-temperature thermocouple assembly.

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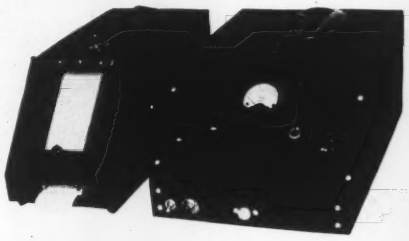

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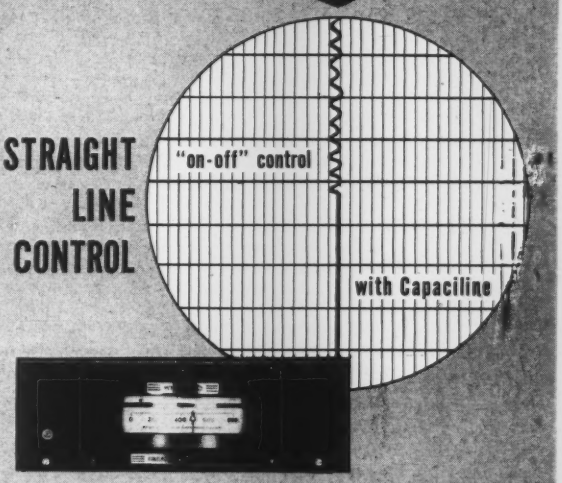

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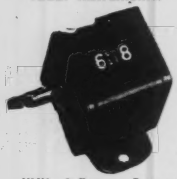

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cause of surges set up during reversal. Bellows-type instruments, which go out of calibration when overranged, have proved particularly unreliable. Mercury columns with adequate surge capacity, and instruments with cut-off valves actuated by the reversal timer have given good service. However, the chance of mercury entering the low-temperature system from the former, and the complexity of the latter make either solution less than satisfactory.

The measurement of flow of gases at low temperature by means of orifice and venturimeters has proved adequate with the exception previously noted for the measurement of differential pressure. Experience with pitot venturimeters has not been satisfactory. With pressure drop contributing a substantial part of the power cost of the plant, the use of essentially zero-pressure-drop pitot venturimeters would be highly advantageous. The reason for their failure to date is not definitely known; it is probably due to plugging of the openings with a small particles of water or carbon-dioxide ice.

The only liquid stream requiring flow measurement is the nitrogen reflux, which was discussed previously.

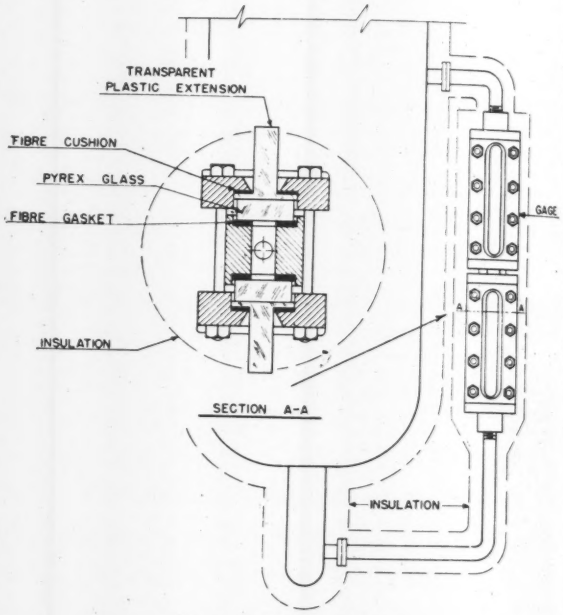

Fig. 8. Modified gage glass.

A visual indication of the level of cold liquid in a vessel has proved useful as a check on mechanical indicators. A conventional gage glass would, of course, quickly become coated with opaque ice. However, a modification using a deep Lucite window has proven satisfactory (Fig. 8). The heat leak through the window is so small that the amount of boiling which occurs in the glass does not seriously affect the indication of level.

One important factor in the power requirement of oxygen production is heat leaking into the cold sections of the plant from the ambient atmosphere. Added refrigeration must be supplied to offset this heat leak. Although the leak is minimized by the use of insulation, it is still significant. Also, during operation faults may develop in small areas of insulation. Local heat-leak measurements have been made with some success by means of thermopiles encased in a low-conductivity pad (Fig. 9). This particular device was constructed and calibrated in the field by H. P. Hnilicka[2] of Carthage Hydrocol, Inc. Soft rubber was selected because the thermopile could be sealed within the pad by vulcanization, and the soft rubber accommodates itself to surfaces which are not exactly flat. A special calorimeter was used to calibrate the unit; the heat flow was measured as a function of the temperature difference across the pad. A reliable and accurate instrument based

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*Vandaveer, *Industrial & Engineering Chemistry, Vol. 22, page 596, June 1930.*

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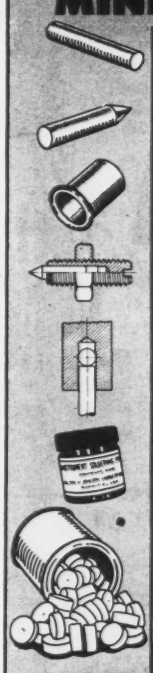

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on the principle used by Hnilicka (or on any other principle) which could be purchased rather than developed in the field would be extremely useful to the oxygen producer.

In the simple tonnage-oxygen plant, inspection of the product consists solely of analyzing the product streams for oxygen. This can be done adequately by the use of a modified Orsat absorption unit. A continuous record of oxygen content of the oxygen product is being made in two large plants, using magnetic-type analyzers developed from the earlier Pauling oxygen meter. Such instruments have proved reliable and convenient. The only other chemical analysis of importance is the determination of acetylene in the reboiler liquid. This analysis is carried out in the chemical laboratory, using a modification of the method of McKoon and Eddy[3].

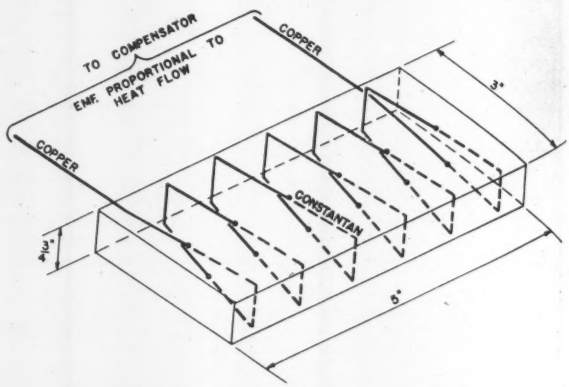

Fig. 9. Rubber pad and thermopile for measuring heat flow.

SUMMARY

Instrumentation, being an integral part of the design of an oxygen plant, must be planned to minimize the overall cost of producing oxygen. This requires a knowledge of the workings of an oxygen plant. The unusual design characteristics of oxygen plants, which determine the general type of equipment and instruments required, have been described. A general outline of the HRI oxygen plant was presented with particular emphasis on the services and functioning of the control system. Other instrumentation used to measure process variables of the cold section of the plant were described also.

ACKNOWLEDGEMENT

The author wishes to acknowledge the great aid received from the many suppliers of instruments for HRI oxygen plants, whose products have helped to make possible the accomplishments described in this article. The author also wishes to thank K. Tsunoda of Hydrocarbon Research, Inc., for his critical review.

REFERENCES

(1) Swearingen, Judson S., *Transactions American Institute of Chemical Engineers*, Vol. 43 No. 2, pp. 85-90 (1947).

(2) Hnilicka, H. P., Carthage Hydrocol, Inc., Private Communication (1950).

(3) McKoon and Eddy, *Industrial and Engineering Chemistry*, Vol. 18, No. 2, p. 133 (1946).

DISCUSSION

H. C. Givens: As brought out by Mr. Arnold, the head instrument man must first be a good process man and also have some knowledge of finance to be able to tell what is economical to use. Mr. Arnold made one statement that I would like explained. If more oxygen or higher-purity oxygen is desired from a plant operating efficiently, the flow of air must be increased. Just why is that?

Arnold: The reason why more air is needed if higher-purity oxygen is desired is that the greater the degree of fractionation required, the lower the recovery of oxygen. In other words, the yield of 95 percent oxygen from a unit of air is greater than the yield of oxygen of 97 percent purity because it takes more work to do the additional fractionating required.

Givens: There undoubtedly has been a great deal of thought about the control of these oxygen plants. Have you

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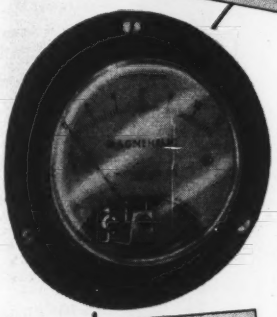

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ever tried rotameters with electrical connections to measure liquid flows, in place of the orifice meters?

Arnold: No, we have not.

Givens: On the liquid-level controllers, have you ever tried the internal-flow type or the geiger-counter type that has no connection inside your vessels?

Arnold: No. We have used the displacement meter, or we did use it in the first plant. It worked very well, and when we find something that works well, we are reluctant to change. But I have no doubt that there will be developed, or are possibly available now, better methods of control of the liquid level than we have used.

Henry Beekman: Mr. Arnold, has your company done anything on the continuous analyzing of a stream for acetylene?

Arnold: We have not. I would like to ask if you have.

Beekman: Yes, we have tried infrared analysis; however results are erratic and the concentration is so low that it is difficult to do anything on a continuous basis. At least that is our experience today.

Givens: Mr. Arnold, do you have any automatic controls which provide for reversal of units in the plant?

Arnold: No, I have described all the automatic control equipment that we use. We find that these plants run well without it, and I think you undoubtedly have more experience than I have with the German plants—particularly the smaller ones that are offered for sale now. They have an extremely small control-board and few, if any, automatic equipments. We have not tried to make our instrumentation more automatic than I have described.

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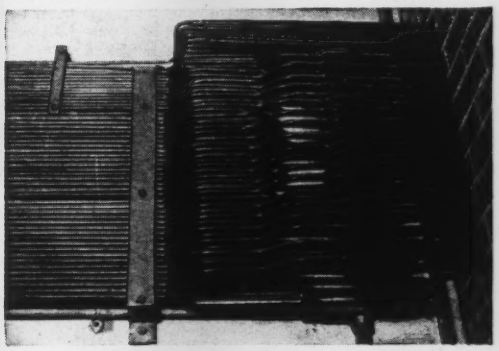

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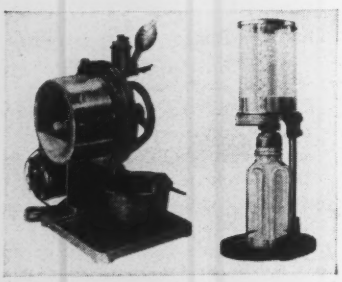

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Instrument Electronics—Test Items

Continued from page 331

8-6. The plate efficiency of a vacuum tube is the ratio of
(a) grid input power to plate output power
(b) grid current to plate current
(c) output signal power to d-c. input power
(d) output signal power to input signal power

8-7. Most triode power-amplifier circuits have a load impedance that is
(a) smaller than the plate impedance of the tube
(b) equal to the plate impedance of the tube
(c) 2 or 3 times greater than the plate impedance of the tube
(d) much greater than the plate impedance of the tube

8-8. Class-A amplification differs from class-AB amplification in that the former has
(a) less distortion
(b) less efficiency
(c) less bias
(d) all the above

8-9. A large signal to a class-A amplifier can produce
(a) cut-off distortion on positive peaks
(b) grid-current distortion on negative peaks
(c) distortion on either peak
(d) all the above

8-10. A class-B amplifier differs from a class-C amplifier in that the former has
(a) no distortion
(b) higher efficiency
(c) less bias
(d) all the above

8-11. Class-C operation differs from class-B operation in that the former has
(a) higher efficiency
(b) more distortion
(c) greater bias
(d) all the above

8-12. An amplifier designed to amplify a small pickup signal with no distortion should be operated
(a) class A
(b) class B
(c) class C
(d) class D

8-13. An audio-amplifier stage designed to drive a loudspeaker that requires considerable power should be operated
(a) class A
(b) class B (single-stage)
(c) class B (push-pull)
(d) class C (single-stage)

8-14. A single-stage class-B amplifier stage with a resonant-tank plate load can produce an output signal with low distortion because of
(a) small bias
(b) small load impedance
(c) flywheel action
(d) push-pull action

8-15. Amplitude, phase, and frequency distortion are alike in that each
(a) changes the shape of the signal
(b) is caused by nonlinearity of the characteristic curve
(c) results from improperly designed coupling networks
(d) can do all the above

8-16. The stages of a 5-stage voltage amplifier have gains of 10, 100, 70, 20, and 20. The input signal required to give an output signal of 28 volts is
(a) 1 microvolt
(b) 1 millivolt
(c) 220 microvolts
(d) 220 millivolts

8-17. In an RC-coupled amplifier, the reactance of the coupling capacitor affects the frequency response primarily at
(a) low frequencies
(b) mid band
(c) high frequencies
(d) all the above

8-18. In an RC-coupled amplifier, the plate load resistance affects the frequency response primarily at
(a) low frequencies
(b) mid band
(c) high frequencies
(d) all the above

8-19. The coupling capacitor in an RC-coupled stage can not have very high capacitance because
(a) low-frequency signals will be blocked
(b) the tube will be blocked by a large signal
(c) high-frequency response will be reduced
(d) the tube can be burned out

8-20. An advantage of impedance coupling over RC coupling is that the former has
(a) better frequency response
(b) fewer components
(c) less d-c. plate load resistance
(d) lower operating plate voltage

8-21. An advantage of transformer coupling over RC coupling is that the former has
(a) gain in the coupling network between stages
(b) less d-c. plate load resistance in the first stage
(c) less d-c. resistance in the grid circuit of the second stage
(d) all the above

8-22. A disadvantage of direct-coupled d-c. amplifiers is
(a) instability
(b) low gain
(c) poor frequency response
(d) all the above

8-23. A chopper-type amplifier differs from a direct-coupled amplifier in that the former
(a) amplifies a-c. signals only
(b) amplifies d-c. signals only
(c) uses a-c. coupled stages
(d) has less gain

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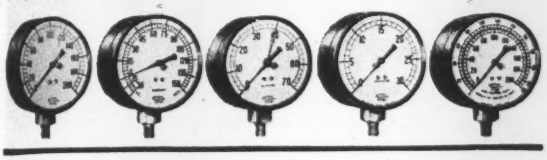

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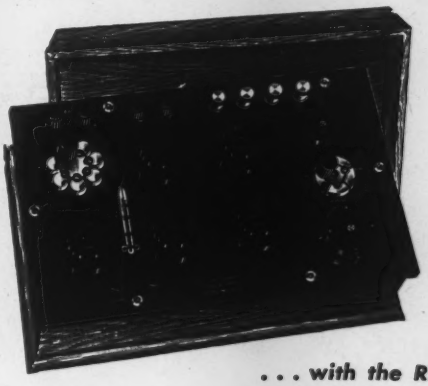

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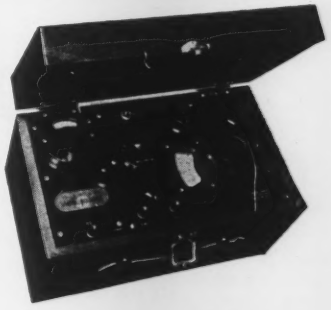

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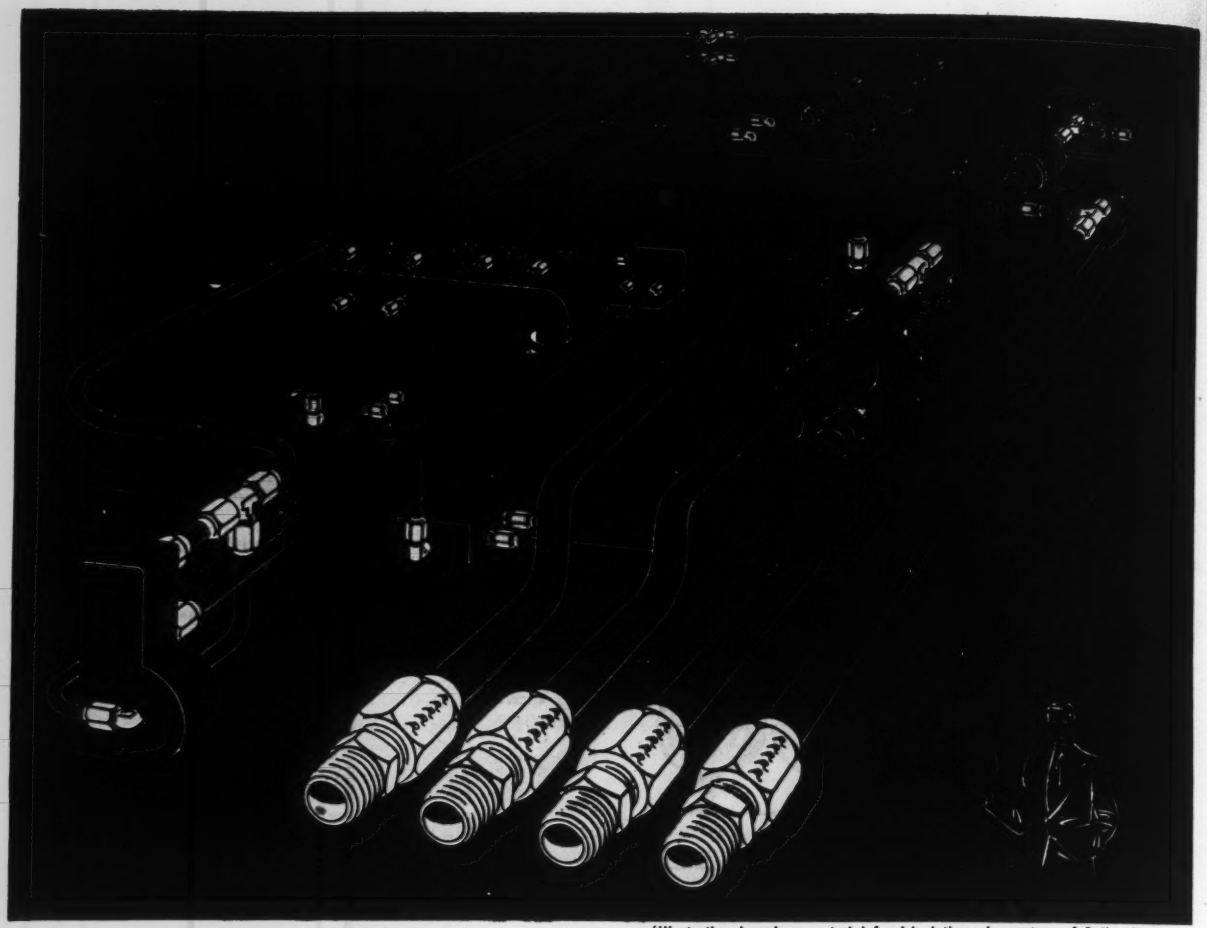

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Mercury—The Purest Metal

Continued from page 312

gold. If mercury is caused to flow through a ring of gold surrounding an aperture set in a tube, the mercury forms a metallic bond with the gold. The bond stops any contaminants from creeping between the side walls and the liquid, a phenomenon occurring whenever mercury is in movement. It is the same phenomenon which causes the oil in one leg of an oil-pressure manometer to work through and appear on top of the other leg, and which causes the escape of nitric acid through the mercury seal of an acid tower. In the gold-adhesion filter tube, the mercury which passes through the gold ring is drawn from the body of the fluid and thus does not carry any surface contaminant.

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Although mercury is the purest metal obtainable, maintenance of this purity requires careful attention.

BIBLIOGRAPHY

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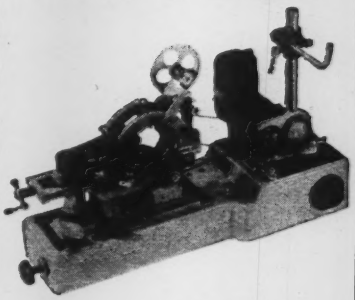

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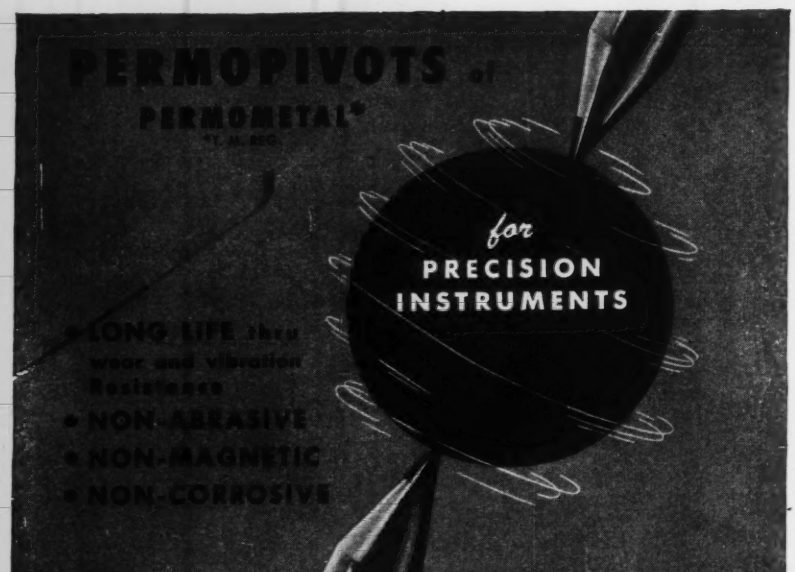

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New Jersey Section, ISA, Symposium "Use and Application of Control Valves." For information write L. H. Ballinger, 2371 Channing Ave., Westfield, N. J.

April 3-4
Instrument Society of America, Pittsburgh Section.
Second Annual Regional Conference, "Instrumentation for the Iron and Steel Industry." Roosevelt Hotel, Pittsburgh.
For information write W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa.

April 3-8
36th Annual Exhibition of Scientific Instruments and Apparatus, Royal College of Science, London, England. For information write Physical Society, 1 Lowther Gardens, London, S.W. 7, England.

April 27-May 6
Heavy Industries Fair, Hanover, Germany. This fair includes exhibits of instruments for measurement, inspection, testing and control. For information write Deutsche Messe- und Ausstellungs-A.G., Hannover, Messegelaende, Germany.

May 1952
American Association of Spectrographers. Symposium on "Instrumental Methods of Analysis in the Non-Ferrous Industry." Contributed papers in this field are invited, write to Robert Raisig, c/o Apex Smelting Co., 2537 W. Taylor St., Chicago 12, Ill.

May 2-3
Association for Computing Machinery, Spring meeting. For information write F. A. Schwertz, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh 13, Penna.

May 4-8
Electrochemical Society, Fiftieth Anniversary Meeting, Benjamin Franklin Hotel, Philadelphia. Sessions on Instrumentation have been scheduled. For information write Dr. Henry Linford, Sec., 235 West 102 St., New York 25.

May 5-16
British Industries Fair. Earls Court & Olympia, London includes laboratory and scientific instruments; Castle Bromwich, Birmingham, includes industrial instruments. For information write Board of Trade, Imperial Chemical House, London, S.W.1, England.

May 6-9
Scientific Apparatus Makers Association.
Annual Meeting of all Sections.
Edgewater Beach Hotel, Chicago.

May 7-9
Institute of Radio Engineers.
National Conference on Airborne Electronics.
Biltmore Hotel, Dayton, Ohio.
For information write E. K. Gannett, 1 East 79th St., New York 21.

May 13
American Association of Spectrographers Symposium "Instrumental Methods of Analysis in the Non-Ferrous Industry," Society of Western Engineers Building, 84 E. Randolph St., Chicago, Ill. For information write Robert Raisig, c/o Apex Smelting Co., 2537 W. Taylor St., Chicago 12, Ill.

May 14-16
Society for Experimental Stress Analysis, Spring meeting, Lincoln Hotel, Indianapolis, Ind. For information write V. H. McNeilly, 1207 Parkway Court, Lafayette, Ind.

May 16-17
Southwestern Institute of Radio Engineers.
Conference and Radio Engineering Exhibit.
Rice Hotel, Houston, Texas.

May 18-25
Achema X—Chemical Meeting and Exhibit. Frankfurt, Germany. At the same time and place the 25th International Congress for Industrial Chemistry will be held. Instruments will be exhibited. For information write Dr. H. Bretschneider, Deutsche Gesellschaft fuer Chemisches Apparatewisen, Frankfurt am Main 13, P.O. Box 1337, Germany.

May 22-23
"Electronics and Machines" Symposium, Professional Group on Industrial Electronics, Institute of Radio Engineers, Palmer House, Chicago. For information write Eugene Mittelmann, 549 W. Washington Blvd., Chicago 6, Ill.

May 22-24
American Society for Quality Control, Onondaga Memorial, Syracuse, N. Y. For information write W. R. Weaver, Gen. Chm., 1527 Republic Bldg., Cleveland 1, Ohio.

June 11-13
American Congress on Surveying and Mapping Twelfth Annual Meeting and Exhibit.
Shoreham Hotel, Washington, D. C.
For information write Walter S. Dix, Ex. Sec., P. O. Box 470, Benjamin Franklin Station, Washington 4, D. C.

June 19-21
ASME Applied Mechanics Division Symposium on Shock and Vibration Instrumentation, Pennsylvania State College, State College, Pa. For information write W. D. Kroll, Physicist, National Bureau of Standards, Washington 25, D.C.

June 23-27
ASTM 50th Anniversary Meeting and 10th Exhibit of Testing Apparatus and Laboratory Supplies, Hotel Statler, New York, N. Y. For information write Robert J. Painter, Asst. Sec., American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Sept. 4-13
International Society of Photogrammetry, Shoreham Hotel, Washington D. C. For information write L. Ray Smart, U. S. Geological Survey, Trimetrogon Section, Washington 25, D. C.

Sept. 8-12
Instrument Society of America.
Seventh National Instrument Conference and Exhibit.
Public Auditorium, Cleveland, Ohio.

Sept. 29-Oct. 1
Eighth National Electronics Conference and Exhibition.
Sherman Hotel, Chicago.
For information write Karl Kramer, Ex. Sec., 852 E. 83rd St., Chicago 19.

October
Scientific Apparatus Makers Association.
Midyear Meeting of Recorder-Controller Section.
Seaview Country Club, Absecon, N. J.

Nov. 5-9
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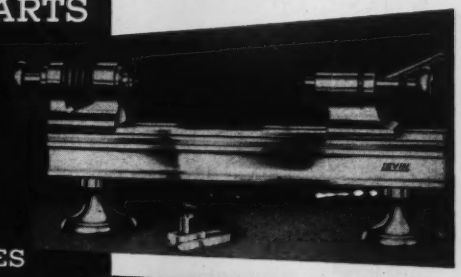

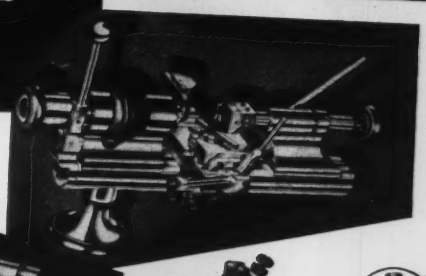

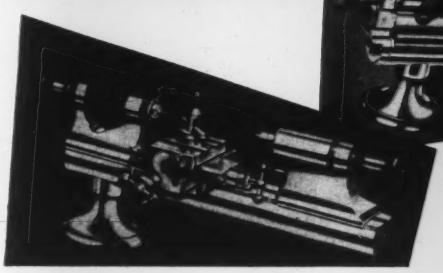

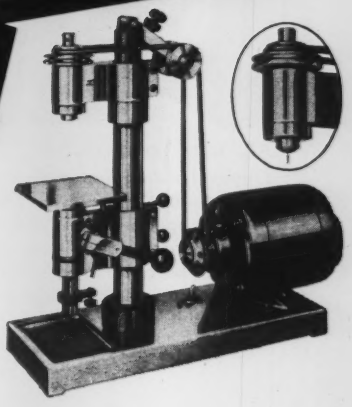

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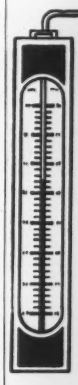

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U-178 **Temperature Control.** 4-page Specification Sheet 609 describes "Electr-O-Vane" indicating and recording temperature controllers with snap-action electric contacts.—Sta. 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Windram Aves., Phila. 44, Penna.

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U-181 **Temperature Control.** 4-page Vol. 11, No. 2 issue of "Wheelco Comments" presents articles on use of "Capacilog" temperature controller-recorders in aluminum and magnesium molding and casting, and on paint-drying ovens.—Wheelco Instruments Co., Harrison & Peoria Sts., Chicago 7, Ill.

U-182 **Contact-type Controllers.** 4-page Bulletin G1 describes "Sim-plytrol" electric-contact type indicating automatic controllers which operate on as little as 0.5 microampere or 0.1 millivolt full-scale from primary elements for temperature, displacement, speed, etc.—Assembly Products, Inc., Main at Bell St., Chagrin Falls, Ohio.

U-183 **Temperature Control.** 52-page illustrated Catalog 400 describes maker's large line of "Thermoswitch" temperature controllers. Includes features, operation, installation, and selection data. Reaction time, thermal and electrical specifications are given in comparison with competitive products.—Fenwal, Inc., Ashland, Mass.

U-184 **Surface-temperature Thermometer.** 1-page illustrated Data Unit 206 covers features and application of new small "Pandux Model 310" surface-temperature thermometer.—Pacific Transducer Co., 11921 W. Pico Blvd., Los Angeles 64, Calif.

U-185 **Industrial Freezers.** 4-page specification bulletin lists 45 models capable of maintaining temperatures of minus 165 deg. F.—Webber Appliance Co., Inc., 2740 Madison Ave., Indianapolis, Ind.

U-186 **Chilling Machines.** 8-page

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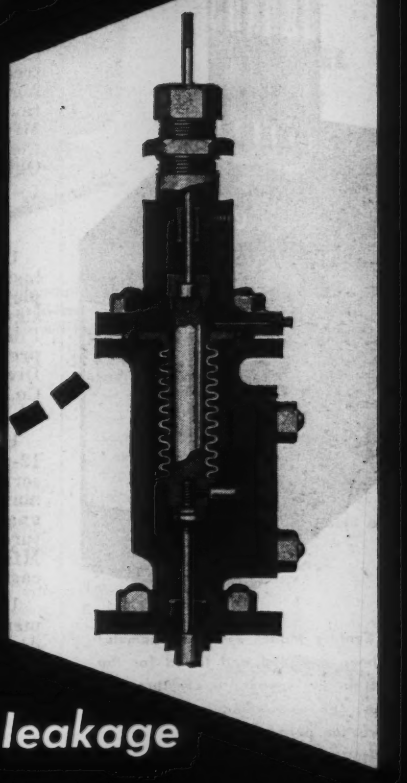

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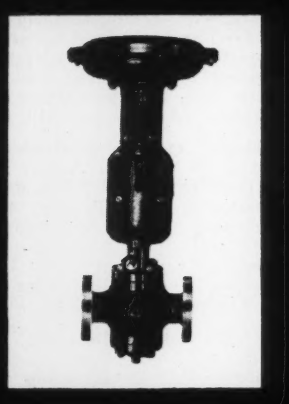

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folder describes advantages of low-temperature metal treatment; gives technical data on methods and results of chilling various metals and alloys. Standard and special chilling machines are illustrated and described with specifications.—Sub-Zero Products Mfg. Div., Deepfreeze Distributing Corp., 3928 Reading Rd., Cincinnati 29, Ohio.

U-187 **Chilling as a Metallurgical Process.** 16-page illustrated reprint describes techniques in shrinking metal, treating and seasoning tool steels, testing metals and materials, and applications in industries.—Sub-Zero Products Mfg. Div., Deepfreeze Distributing Corp., 3932 Reading Rd., Cincinnati 29, Ohio.

Pressure

U-188 **Pressure Control.** 8-page illustrated Bulletin 16-1 presents principle of operation, specifications, and design features of "Honeywell Pressure Pilot" non-indicating pilot-operated pressure controller.—Sta. 40, Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Pa.

U-189 **Pressure and Vacuum Gages.** 12-page catalog illustrates and describes maker's large line of slack-tube manometers, "magnehelic" gages, hook gages, smoke gages, etc. Covers features and specifications.—F.W. Dwyer Mfg. Co., 317 S. Western Ave., Chicago 12, Ill.

U-190 **Dynamic Pressure Measurements.** 4-page bulletin illustrates and describes new "Model DG-101 Dyna-Gage" for measuring static and dynamic pressures under extremely adverse conditions as in jet and rocket studies.—Photocon Research Products, 1062 N. Allen Ave., Pasadena 7, Calif.

U-191 **Gas-pressure Control.** Data Sheet 7.2-5 describes gas distribution control system for consumer areas which has eliminated complaints.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Phila. 44, Penna.

Flow

U-192 **Flow Meters.** 40-page Bulletin F1605 is a detailed and profusely-illustrated catalog of "Series 500" mechanical and electrical recording, integrating, and controlling flowmeters for steam, air, gas, oil, water, acids, etc. Included are telemetering systems.—The Bristol Co., Waterbury 20, Conn.

U-193 **Area-type Flowmeters.** 8-page Publication 10529 describes "Flowrator" instruments with new "Predictable" metering float which makes it possible to stock flowmeters for immediate shipment.—Fischer & Porter Co., Hatboro, Penna.

U-194 **Pumps.** 12-page illustrated Bulletin W-350-B11A describes centrifugal pumps for chemical and process industries. Also "Worthite" valves and mechanical pump seals for corrosive liquids.—Worthington Pump & Machinery Corp., Harrison, N. J.

Optical

U-195 **Optical Tooling Instruments.** 6-page Bulletin 808 illustrates and describes new alignment telescope with built-in autocollimating feature, and unusual optical square for use with telescope. Includes features and advantages.—Farrand Optical Co., Inc., Bronx Blvd. and E. 280 St., New York 70, N. Y.

U-196 **Photographic Supplies.** 72 page illustrated catalog describes cameras, accessories, and darkroom supplies.—Burke & James, Inc., 321 S. Wabash Ave., Chicago 4, Ill.

U-197 **Ephemeris.** 92-page 1952 Edition "Service Booklet L" includes tables of solar ephemeris for 1952. Encloses Almanac Supplement of 28 selected stars. Also descriptions of maker's transits and other topographic instruments.—W. & L. E. Gurley, Troy, N. Y.

Thickness

U-198 **Thickness and Density Gage.** 8-page Bulletin R-52 describes use of "Model R AccuRay Beta Gauge" in rubber and plastics industries.—Industrial Nucleonics Corp., 1205 Chesapeake Ave., Columbus 12, Ohio.

U-199 **Thickness Gage.** 4-page illustrated bulletin describes maker's "Elcometer" dry-film self-contained thickness gage for paint, rubber, textiles, ceramics, or any non-magnetic coating on magnetic surface.—Gardner Laboratory, Inc., Bethesda 14, Md.

Combustion

U-200 **Combustion Control.** 8-page case history describes operation of the largest independent producer of electric power for manufacturing in Connecticut, including equipment, operating philosophy, and combustion-control system.—The Hays Corp., Michigan City, Ind.

U-201 **Combustion Control.** 24-page illustrated Bulletin 1023 describes maker's line of combustion controllers for oil-fired and gas-fired boilers. Includes principles of operation, records, components of equipment, and typical installations.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

U-202 **Oxygen Analyzer.** 4-page illustrated Instrumentation Data Sheet 10.15-9 describes Beckman "Oxygen Analyzer" with Brown "ElectroniK" recorder. Covers applications, operation, equipment, specifications, and features.—Sta. 40, Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-203 **Smoke Detector.** 2-page Bulletin AC-2 illustrates and describes maker's "Air-conditioning Smoke Detector" that automatically shuts down circulation in air-conditioning ducts on presence of smoke. Includes principle and specifications.—Ess Instrument Co., Bergenfield, N. J.

U-204 **Signal Equipment.** 32-page illustrated Bulletin HSE-1 describes complete line of commercial signal equipment, including visual annunciators, fire alarm stations, in-and-out reg-

isters, program bell transfer panels, silent paging systems, sectional cable terminals, etc.—Cannon Electric Co., P. O. Box 75, Los Angeles 31, Calif.

Level

U-205 **Bin-level Indicator.** Announcement sheet describes "Bin-Vue" indicator which gives positive signals under pressure or vacuum; usable with any bulk material "from feathers to lead."—Convair Corp., 4153 Library Rd., Pittsburgh, Penna.

U-206 **River-stage Recorders.** 8-page Dec. 1951 issue of "The Hydromite" features article on miniature Mississippi basin at the U. S. Waterways Experiment Station.—Leupold & Stevens Instruments, Inc., 44.5 N.E. Glisan St., Portland 13, Ore.

Radioactivity

U-207 **Radiation Detectors.** 8-page Bulletin GEA-5735 describes new radiation detectors, including radiation monitor, scintillation counter, portable radiation probe, area health monitor, gamma survey meter, alpha hand counter, ionization chamber, counter tube, thermocouple vacuum gage, and impulse counter.—General Electric Co., Schenectady 5, N. Y.

Inspection and Testing

U-208 **Quality-control Inspection.** 4-page Bulletin GEA-5738 illustrates and describes new "Continuous Sampling Monitor" that simplifies quality control and eliminates 100-percent inspection. Includes photographs, diagrams, and operation.—General Electric Co., Schenectady 5, N. Y.

U-209 **Stress Analysis.** 8-page Form 765-A illustrates and describes "Type 1534-A" dynamic polariscope for photoelastic stress analysis. Covers features, advantages, principles, and construction. —General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-210 **Abrasion Test Set.** 6-page Bulletin 5003 describes "Model 140 Abraser" for measuring abrasion resistance of surfaces on quantitative basis.—Taber Instrument Corp., 111 Goundry St., North Tonawanda, N. Y.

U-211 **Test Instruments for Paint** 36-page catalog describes eighty instruments, accessories, etc., for determining various physical properties of paints, varnishes, etc.—Gardner Laboratory, Inc., Bethesda, Md.

U-212 **Ultrasonic Inspection.** 4-page Specification Sheet No. 11549 describes "Model MS-100" ultrasonic instrument for measuring thickness and detecting internal flaws.—Photocon Research Products, 1062 N. Allen Ave., Pasadena, Calif.

U-213 **Tensile-test Furnaces.** 4-page illustrated bulletin describes tubular furnaces and control panels for tensile, creep, and stress-rupture tests of steels and alloys.—Marshall Products Co., 270 W. Lane St., Columbus 2, Ohio.

U-214 **Compression Tester.** 4-page Bulletin 15 describes: "Model U-12L" 1500-lb. scale type compression apparatus, "Model U-13L" hydraulic compres-

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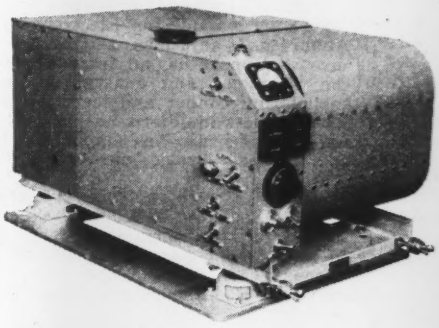

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FEATURES:

Size: 20" long, 12½" wide, 8⅞" high.

Weight: 60 pounds.

Number of Recording Channels: 6 to 50.

Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.

Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.

Paper speeds continuously and instantly variable without changing gears or sprockets.

Separate optical system for viewing before or during recording.

Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.

Data numbering at beginning of record.

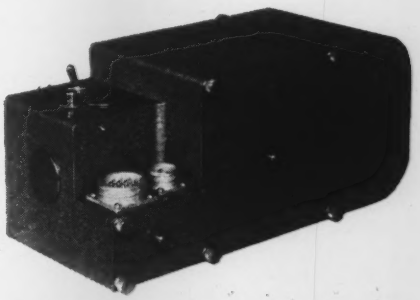
Footage indicator showing amount of paper remaining in magazine.

Automatic record length control.

Trace identification.

Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

Size: 5" x 5" x 11".

Weight: 11 pounds.

Cast Aluminum case.

Paper speeds variable ½" to 12" per second.

Detachable daylight loading magazine with a capacity of 3⅜" x 50' paper or film.

2 to 12 individual channels.

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sion apparatus, and "Model U-14L" 125-lb. scale type hydraulic testing machine. —Labquip Corp., 4520 W. North Ave., Chicago 39, Ill.

Telemetering

U-215 **Telemetering.** 4-page illustrated Instrumentation Data Sheet 9.1-9, describes Westinghouse "Freq-O-Tron" telemetering equipment as used with Brown "ElectroniK" recorders for long distance telemetering of system variables to central location. Discusses system requirements, principles, application, operation, and features.—Sta. 40, Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

Air

U-216 **Humidity.** 16-page booklet "The Moisture in Our Atmosphere" gives detailed illustrated description of the nature, behavior, and measurement of atmospheric moisture. Also maker's adsorption-type dehumidifying equipment.—Pittsburgh Lectrodryer Corp., Pittsburgh, Penna.

U-217 **Air Filters.** 16-page Technical Report discloses a new method of testing and rating air filters, enabling designers and users to select filtration equipment on a scientific quantitative basis.—Farr Co., P.O. Box 10187, Airport Sta., Los Angeles 45, Calif.

U-218 **Air Cleaner and Dryer.** Bulletin B30 describes in technical detail new "Model B30 Condensifilter" which has a capacity of 30 scfm. at 100 psi. with a pressure loss of less than 2 psi at rated capacity.—Hankinson Corp., 1501 Beaver Ave., Pittsburgh 33, Penna.

U-219 **Air and Gas Compressors.** 4-page Bulletin 202-A features description and double page longitudinal section of a 9-inch-stroke "Oilfreair" compressor.—Pennsylvania Pump and Compressor Co., Easton, Penna.

Chemical Laboratory

U-220 **Laboratory Equipment.** 16-page Catalog 5201 describes laboratory furnaces, furnace control instruments, carbon determinator, automatic timer, etc.—Boder Scientific Co., 719 Liberty Ave., Pitttsburgh 22, Penna.

U-221 **Hydrocarbon Detector.** Bulletin DD-1 describes new "MSA Aromatic Carbon Detector" for determination of toxic concentrations of benzene, toluene and xylene.—Mine Safety Appliances Co., Braddock, Thomas & Meade Sts., Pittsburgh 8, Penna.

U-222 **Chemical Instrumentation.** 32-page Vol. 21 No. 3 issue of "The Laboratory" announces and describes new products including: standardized apparatus for paper chromatography, a flame attachment for the spectrophotometer, an improved metallographic polisher, new certified precision burettes, and new chemical reagents.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.

U-223 **Laboratory Clamps.** New and enlarged clamp catalog has 12 pages, features new "Alumaloy" clamps with several novel grips, etc.—Laboratory Industries, Inc., 4710 West North Ave., Chicago 39, Ill.

U-224 **Desiccator.** Folder describes "Pluro-Jar" desiccator with adjustable shelves for crucibles, etc.—Bethlehem Apparatus Co., Inc., Hellertown, Penna.

U-225 **Electro-analysis.** 24-page "Working Manual for Electro-analysis Apparatus" describes setting-up and care of apparatus, an introduction to the technique, and general conditions for plating copper and lead, including interferences in determination. Includes analysis of brass for copper and lead. —Eberbach Corp., Ann Arbor, Mich.

U-226 **Electro-analysis Apparatus.** 4-page illustrated Bulletin 130 describes apparatus for quantitative analysis of metals by electro-deposition method. Discusses construction, operation, applications.—Eberbach Corp., Ann Arbor, Mich.

U-227 **Chemical Analysis.** 16-page illustrated booklet describes maker's "Nefluoro-Photometer" which makes chemical analysis by colorimetry, fluorometry, and nephelometry in one electronic-optical system. Covers features, applications, parts, assemblies, and accessories.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.

U-228 **Marking Tape.** Several bulletins and folders (with samples attached) describe "Labelon" pressure-sensitive tape on which user can write and which becomes waterproof label.—Nevis Industrial Specialties Co., 29-10 Northern Blvd., Long Island City 1, N. Y.

U-229 **Laboratory Equipment.** 30-page No. 74 issue of "Cenco News Chats" features articles on tensiometers, vapor pressure, sound velocity, glass tester, pH meter, and other chemical laboratory instruments.—Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.

Chemical Process Analysis

U-230 **Spectrophotometer.** 4-page Data Sheet 10.16-13 describes application, operation, and salient features of new National Technical Labs. direct-transmittancy spectrophotometer, incorporating memory standards to provide recording of absorption spectra on "ElectroniK" recorder.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-231 **Spectrophotometry.** 4-page Instrumentation Data Sheet 10.16-2a illustrates and describes applicability, operation, and features of Beckman "Model IR-2" and "IR-2T" infrared spectrophotometer used with Brown "ElectroniK" recorders. Also describes direct transmittancy recording attachment.—Sta. 40, Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-232 **Analytical Instruments.** 8-page Winter 1952 issue of "The Perkin-Elmer Instrument News" announces a new monochromator and a new infrared spectrometer, both employing a new double-pass system. Also article on electrophoretic study of protein transfer.—The Perkin-Elmer Corp., Norwalk, Conn.

U-233 **Diffraction and Spectrometric Equipment.** 60-page catalog titled "X-ray Diffraction and Geiger-Counter X-Ray Spectrometric Equipment" covers equipment and components (tubes, rectifiers, cameras, monochromators, etc.) Also maker's new electron microscope. —Research & Control Instruments Div., North American Philips Co., Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

U-234 **R-f. Chemical Analyses.** 32-page Winter 1951-52 issue of "Scientific Apparatus and Methods" features a 10-page section reporting characteristics of "Chemical Oscillometer" for chemical analyses by measurements of electrical properties at radio frequencies—E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill.

U-235 **Viscosity Control.** 8-page Bulletin No. V-1000C illustrates and describes maker's viscosity recorders and recorder-controllers. Discusses design, performance, operation.—Norcross Corp., 247 Newtonville Ave., Newton 58, Mass.

U-236 **Distillation.** 4-page Data Sheet 10.16-14 describes "Podbielniak" apparatus with multi-range "ElectroniK" potentiometer for high-temperature fractional distillation studies. Discusses operation, technique, and other pertinent facts.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Phila 44, Penna.

Motors

U-237 **Torque Transmission.** 20-page illustrated bulletin presents features and specifications of "Telesyn" synchro generators, motors, differential generators, differential motors, control transformers, and bearing-mounted control transformers.–Ford Instrument Co., Div. of The Sperry Corp., 31-10 Thomson Ave., Long Island City 1, N. Y.

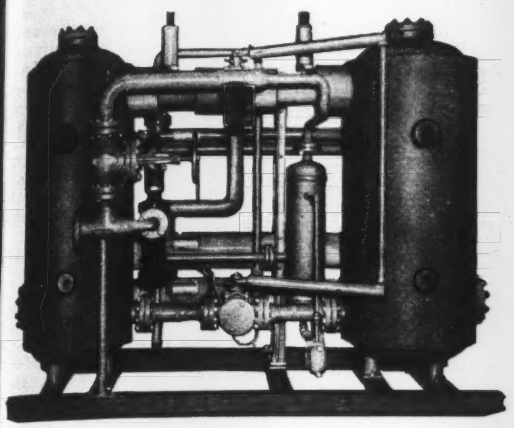
U-238 **Synchro Motors.** 24-page illustrated bulletin presents features, ratings, and specifications of low-inertia and conventional (medium-inertia) servomotors, and synchronous (hysteresis-type) motors.—Ford Instrument Co., Div. of The Sperry Corp., 31-10 Thomson Ave., Long Island City 1, N. Y.

U-239 **Motors.** 4-page Form 943 is condensed price list on induction (wire-wound and squirrel cage), d-c., gear, single-phase and, other type motors. Lists ratings, prices, data.—Century Electric Co., 1806 Pine St., St. Louis 3, Mo.

U-240 **Motor Worms and Gears.** 4-page Vol. 32 No. 1 issue of "Motorgram" features article on materials used for worms and worm gears; also descriptions of new devices using electric motors.—Bodine Electric Co., 2250 W. Ohio St., Chicago 12, Ill.

Tubing

U-241 **Flexible Tubing.** 12-page illustrated brochure presents background



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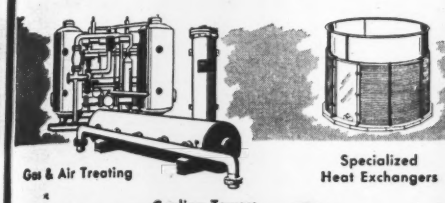

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NEW LITERATURE

events leading to formation of Flexonics Corp. (formerly Chicago Metal Hose Corp.) and corporation organizational setup.—Flexonics Corp., Maywood, Ill.

U-242 **Flexible Shafting.** 64-page "Form 400" catalog presents detailed descriptions and specifications of a wide line of flexible shafts and fittings; contains glossary, discussions, recommendations, etc.–F. W. Stewart Mfg. Corp., 4311 Ravenswood Ave., Chicago 13, Ill.

U-243 **Armored Cable Tubing.** 4-page Bulletin BA-927 illustrates and describes maker's line of flexible protected "Armortube" cable for instrument lines. Includes specifications and applications.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

Electrical and Electronic Instruments

U-244 **Laboratory Standard Bridge.** Jan. 1952 issue of "The General Radio Experimenter" features 4-page article on "Type 1652-A Resistance Limit Bridge" applicable to production testing as well as to precision measurements.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-245 **Variable Autotransformer.** 8-page Form 424-L presents detailed specifications on all models of the "Variac" continuously-adjustable autotransformer for all types of voltage, power, speed and heat control. Last page is a "How to Select" guide.—General Radio Co., Cambridge 39, Mass.

U-246 **Oscillators.** 4-page Vol. 3 No. 4 issue of "hp Journal" covers maker's large line of test oscillators from 0.01 cps. to 10 Mc., including applications, outputs, features, etc.—Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, Calif.

U-247 **Microvolt Recorder.** 4-page Data Sheet 10.0-8 describes characteristics, applicability, operation, and design features of new narrow-span potentiometer circuit for measuring low-level potentials including spans as narrow as 100 microvolts.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-248 **Electrical Test Instruments.** 8-page Bulletin 10A covers maker's line of insulation testing, ground resistance testing, dielectric strength testing, current transformers, voltammeters, and other test instruments.—Associated Research, Inc., 3766 W. Belmont Ave., Chicago 18, Ill.

U-249 **A-c. Power Supplies.** Folder entitled "Portable Packaged Power" features new model of "Voltbox" source of variable a-c. power; also new "Voltbase" for users of "Powerstat" variable transformers.—The Superior Electric Co., Bristol, Conn.

U-250 **Rectifier.** Catalog page and two data sheets give detailed data on "Style RA" 150-amp. continuous-duty selenium rectifier.—Mellaphone Electronic Rectifier Co., Inc., Rochester 2, N. Y.

U-251 **Servicing With Oscilloscope.** 12-page Jan. 1952 issue of "Sylvania News" contains article by J. S. Allen on use of CR oscilloscope in servicing TV sets.—Sylvania Electric Products Inc., P.O. Box 431, Emporium, Penna.

U-252 **FM Receiver.** Specification sheet covers new "842-c" high-precision-grade FM receiver which has laboratory applications in addition to utility in telemetering.—Raymond Rosen Engineering Products, Inc., 32nd & Walnut Sts., Phila. 4, Penna.

Electrical and Electronic Components

U-253 **Electronic Components.** 16-page illustrated catalog No. 972 describes maker's large line of variable capacitors, tube sockets, insulators, pilot lights, connectors, and other components. Includes diagrams, specifications.—E. F. Johnson Co., Waseca, Minn.

U-254 **Electronic Components.** 8-page 1952 edition of general catalog illustrates and describes electronic test instruments, radio and TV kits, components, etc.—Approved Electronic Instrument Corp., 142 Liberty St., New York 6, N. Y.

U-255 **JAN Components.** 48-page "JAN Cross-reference Guide," prepared to facilitate specifying and ordering, covers capacitors, connectors, crystal diodes, resistors, switches, transformers, tubes, etc.—Hudson Radio & Television Corp., 48 W. 48th St., New York 19, N. Y.

U-256 **Radio Parts.** 22-page Catalog 151 lists hundreds of different components and auxiliary devices.—Bud Radio, Inc., 2118 E. 55th St., Cleveland 3, Ohio.

U-257 **Rheostats.** Jan. 1952 issue of "The Ohmite News" features an exploded view with descriptions of maker's rheostats.—Ohmite Mfg. Co., 4835 Flournoy St., Chicago 44, Ill.

U-258 **Tubular Rheostats and Resistors.** 16-page Catalog No. 5 describes standard line, also new models including: fine adjustment rheostat, double rheostat, non-inductive rheostat, miniature slide-wire rheostat, etc. —Rex Rheostat Co., 3 Foxhurst Rd., Baldwin, L. I., N. Y.

U-259 **Potentiometer-rheostats.** 2-page illustrated bulletin describes linear and nonlinear precision potentiometers built to Jan-R-19 specs. Includes features, specification.—DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N. Y.

U-260 **Subminiature "Pot."** 1-page Standard Bulletin 20 illustrates and describes new "Model SR Potentiometer-rheostat" with diameter of only. ⅝ inch. Includes construction and specifications.—Standard Electronics Mfg. Co., 8617 W. 3rd, Los Angeles 48, Calif.

U-261 **Button Ceramic Capacitors.** Issue No. 605 (Nov. 1951) of "Sprague Engineering Bulletin" gives quantita-

tive data on new button ceramic capacitors offering advantages to designers of electronic equipment.–Sprague Electric Co., North Adams, Mass.

U-262 **Paper Dielectric Capacitors.** 24-page Catalog 21 gives detailed specifications of paper dielectric capacitors in accordance with JAN-C-25.–Sprague Electric Co., North Adams, Mass.

U-263 **Limit and Precision Switches.** 4-page Vol. 1 No. 8 issue of "Micro Tips" features novel solutions to ten safety and production problems submitted by users of maker's snap-action switches.—Micro Switch, Div. of Minneapolis-Honeywell Regulator Co., Freeport, Ill.

U-264 **Limit Switches.** Eight two-page Catalog sheets in a tabbed folder provide specifications of limit switches, basic snap-action switches, aircraft specials, etc.—Electro-Snap Div., The Exhibit Supply Co., 4218 W. Lake St., Chicago 24, Ill.

U-265 **Precision Switches.** Vol. 7 No. 1 issue of "Uses Unlimited" features article on the redesign of a perforator with "Micro" units.—Micro Switch Div., Minneapolis-Honeywell Regulator Co., Freeport, Ill.

U-266 **Connectors.** 2-page Bulletin DPM-2 gives specifications and features of maker's rack-and-panel-type multicontact electric connectors.—Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif.

U-267 **Inductance Pickups.** Three condensed specifications and price-list sheets describe "linear variable differential transformers"—devices which convert a mechanical displacement into an electrical output.—Schaevitz Engineering, Crescent Blvd at Drexel Ave., Camden, N. J.

U-268 **"Transducers."** 70-page reference catalog, "A Compilation of Analog Transducers," describes over 500 analog transducers and contains indexed information on function, principle, transfer characteristics, power required, sensitivity, bandwidth, resonant frequency, limitations, etc. Price 50c. —Instrument Div., Allen B. DuMont Laboratories, Inc., 1500 Main Ave., Clifton, N. J.

U-269 **Displacement Transducers.** Catalog sheets 211-1 and 211-2 describe maker's displacement transducers which use rectilinear potentiometers. Includes specifications and dimensions.—Calvin

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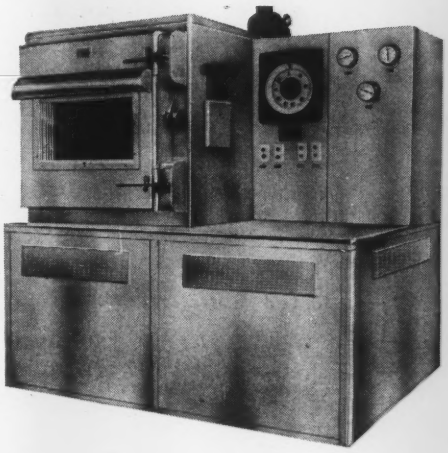

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Laboratories, 12 Court St., Morristown, N. J.

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U-273 **Permanent Magnets.** 20-page illustrated Bulletin PM-100 contains properties of maker's Alnico permanent magnets in tabular form. Includes cast and sintered types; also size and application data.—Carboloy Dept., General Electric Co., Detroit 32, Mich.

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U-275 **Illuminated Panels.** Folder discusses and describes a new method of illuminating control panels, dials, knobs, etc., involving use of a new plastic. Method lends itself to mass production.—Universal Aviation Corp., 230 Park Ave., New York 17, N. Y.

U-276 **Five-way Binding Post.** Folder describes new universal type of electrical connectors having 30-amp. capacity and 1000-volt working voltage.—The Superior Electric Co., Bristol, Conn.

U-277 **Hermetic Seals.** 4-page bulletin gives specifications of glass-to-metal hermetic seals and subassemblies.—The Sealtron Co., 9701 Reading Rd., Cincinnati 15, Ohio.

Acceleration

U-278 **Angular Accelerometers.** 2-page illustrated Bulletin No. 4.5 presents construction features, specifications, selection table, and dimensions of "Series AA5, AA6, and AA7" angular accelerometers.—Statham Laboratories. 12401 W. Olympic Blvd., Los Angeles 64, Calif.

U-279 **Accelerometer Response.** 4-page No. 20 issue of "Instrument Notes" presents reprinted illustrated article "Response of Accelerometers to Transient Accelerations."—Statham Laboratories, 12401 W. Olympic Blvd., Los Angeles 64, Calif.

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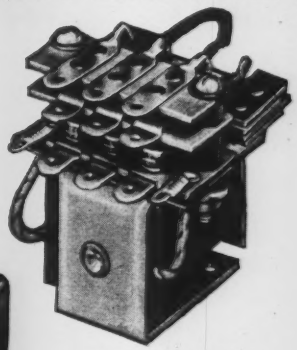

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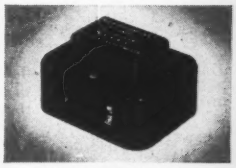

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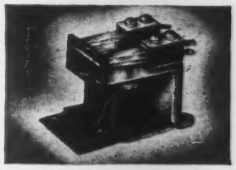

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